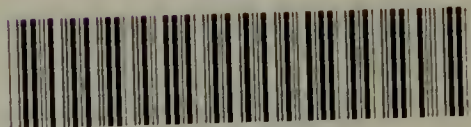


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Supt. of Technical Education, N.S.W.*

BY

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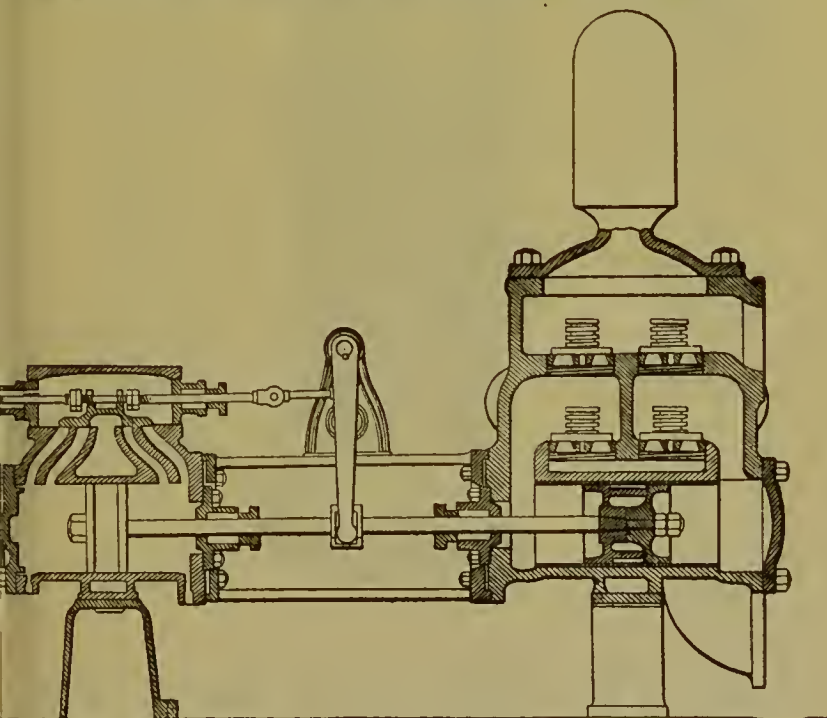
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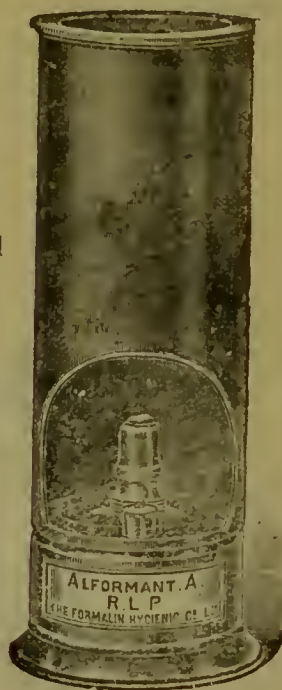
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PREFACE.

By DR. GRESSWELL, M.A., M.D., (OXON).

Chairman of the Board of Public Health and
Permanent Head of the Department of
Health, Victoria.

THE Sanitary Inspector has heretofore looked in vain for a trustworthy, complete, and withal readily understood handbook for guidance in the discharge of the duties of his office. In large part he necessarily looks to the Officer of Health for directions, and the Officer of Health, in turn, is required to give such direction and advice as may be needed ; but it cannot be fair, either to himself or to the Officer of Health, that the Inspector should enter upon his office without a knowledge of the nature and extent of the duties. Nay, more,—in many states and countries an adequate knowledge of those duties is a condition precedent to his appointment by any Sanitary authority. A course of instruction thus becomes essential. It is impossible for any one individual to become completely master of the numerous trades and professions to be appealed to in considering those questions of public health with which the Inspector may be concerned, and a judicious selection accordingly becomes a necessity. Such a selection has been made, and is now presented by the authors of this handbook, and in a form that must prove of the greatest service. The handbook can with the greatest confidence be recommended ; it takes cognizance of all the questions likely to come before the Inspector ; it conveys such information concerning those questions as cannot fail to ensure a sound, practical knowledge of the facts and an intelligent interest in the work in general, and withal, is written in a style that he that runs may read and understand.

A handwritten signature in dark ink, reading "J. Gresswell". The signature is written in a cursive style, with the first letters of the first and last names being capitalized and prominent. The ink is dark and the paper is a light cream color.

ERRATA.

Page 13, line 26— For more heat, read more latent heat.

Page 23— For

$$\frac{h m (t - 32\text{deg.}) - s (t - 62\text{deg.})}{1 + m (t - 32\text{deg.})},$$

read

$$h \frac{m (t - 32\text{deg.}) - s (t - 32\text{deg.})}{1 + m (t - 32\text{deg.})}$$

Page 24, last line— For rooms, read drains.

Page 26, table — For humours, read humus.

Page 28, line 25 — For statuated, read saturated.

Page 42, line 5— For 1400 c, read 1400 a

Page 45, line 15— For parta, read parts.

Page 45, line 15— For protued, read protruded.

Page 47, line 31 — For animalz, read animals.

On page 90,

$$\text{for } C = \left\{ D^2 \times d^2 + (D \times d) \right\} \times .7854 \times \frac{1}{3} \text{ of } H$$

$$\text{read } C = \left\{ D^2 + d^2 + (D \times d) \right\} \times .7854 \times \frac{1}{3} \text{ of } H$$

Page 263, 6th line from bottom —

for— indifferent to make use of it for this reason

read, indifferent to make use of it. For this reason

Page 265, 10th line —

for — the whole charge

read, the whole change

Page 267, 14th line—

for—introduced by

read, introduced in

Page 269, 6th line—

for — of his presence

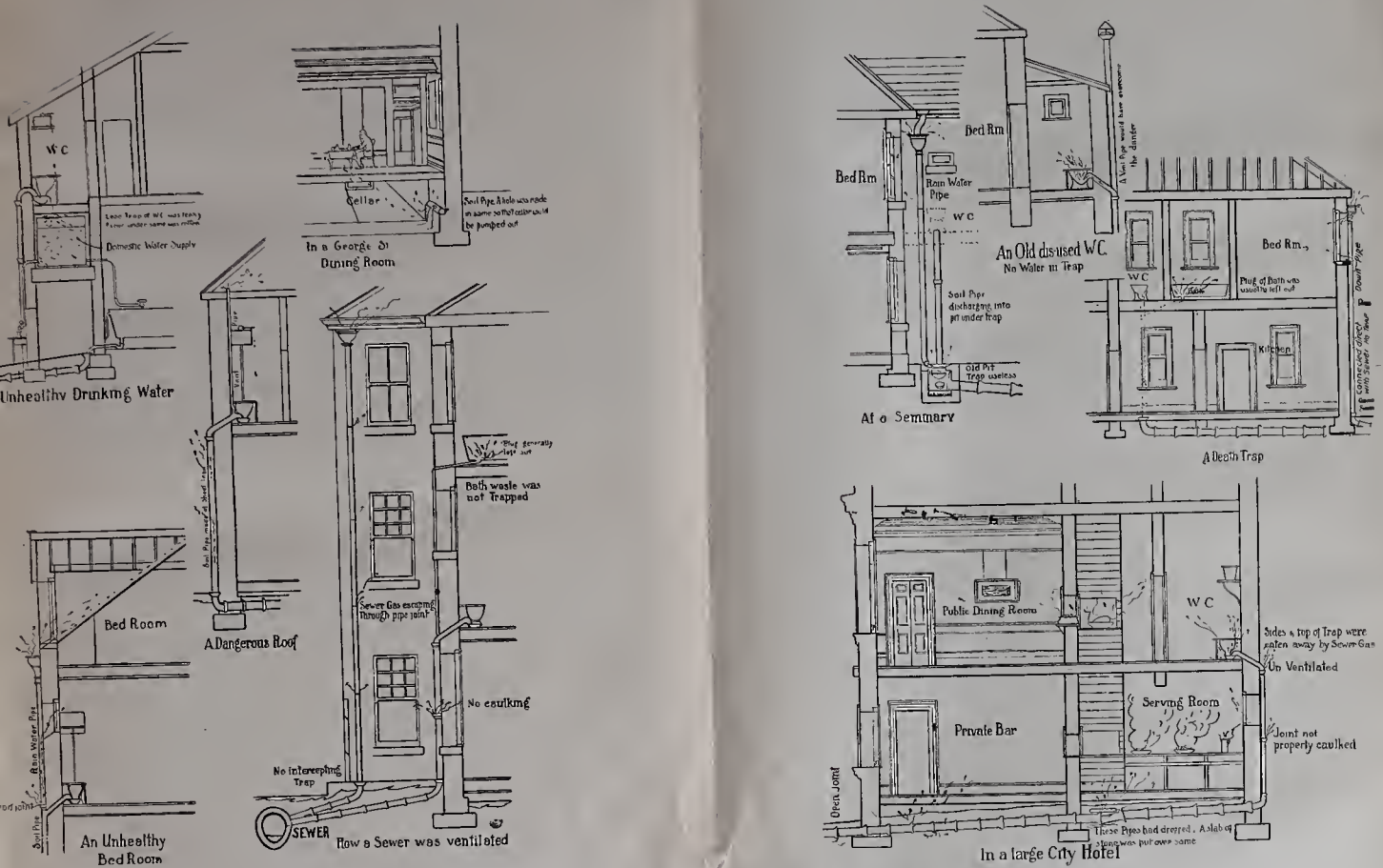
read, of their presence

Page 273, 4th line —

for—Maxima

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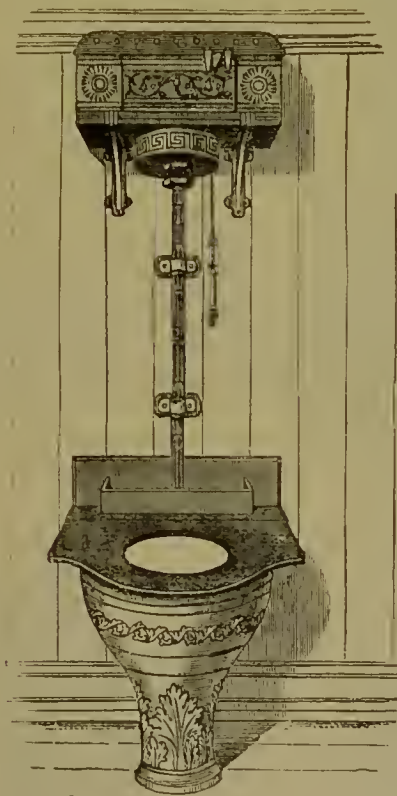
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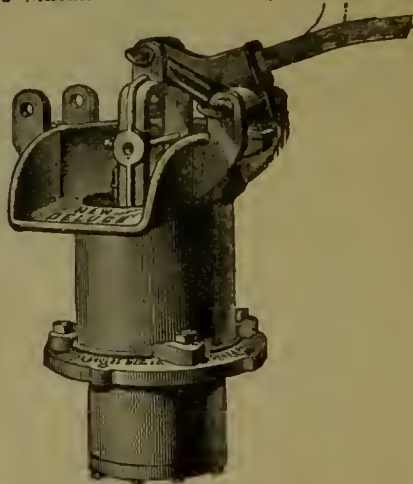
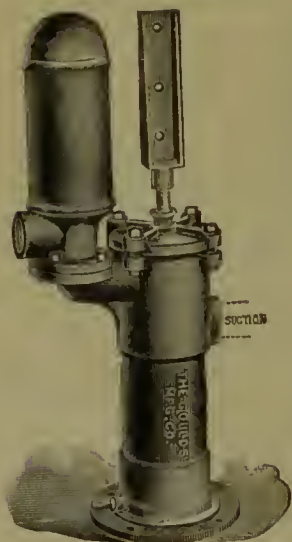
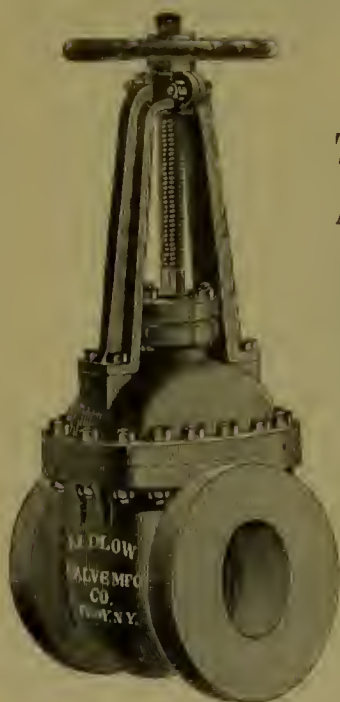
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The
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TEXT-BOOK

CHAPTER I.

SANITARY Science is not founded upon fads and fancies, but rests on the attentive observation of facts and the application of common sense principles to matters of everyday observation. Its principles have been slowly and painfully collected, during a long period, from a careful observation of human disease and misery, and they are not dependent upon the fallacious creation of the so-called theories which spring from mere opinion, without practical knowledge, instead of being founded, as all true theories are, on the practical experiences of generations of former workers. Just as man advanced, slowly and by degrees, from the rude state of barbarism to cultivation and civilisation, so has the research of sanitary science moved on from the first faint glimmer of dawn to the perfect light of day. Industry and experience have brought to perfection those details from which sanitary science is built up, and wherever these details have been carefully and intelligently applied, success has invariably followed their application in the direction of inducing in the community a state of more vigorous mental and bodily health, the diminution of and, in some cases, the complete stamping out of disease, and, as a natural consequence, a vastly decreased death-rate and extended longevity. Sanitary science aims at preventing putrefaction; it cannot materially interfere with Nature's grand law of slow combustion, but it can and does aim at preventing those

evils that are apt to follow the course of putrefaction when that occurs in or near human habitations. The case was put very smartly and truly in a Latin thesis written over a century ago by a young Edinburgh doctor : "It is a law of Nature that those races of animals which fail to adapt *themselves* to their *surroundings* are doomed to perish. Man, however, has learned to adapt his *surroundings* to himself, whereby he is enabled to live in a large measure independent of climate and adverse physical conditions." This statement is especially true in regard to sanitary science in its relation to what has been called the artificial conditions of modern life. Man, in constructing protection for himself against the elements, also constructed conditions of disease, which conditions were also materially increased by the exigencies of life and the suitability of towns or cities for the purposes of trade. Population has increased—especially in certain civilised countries—till, as is the case to-day in Great Britain, the soil has become incapable of supplying food to its teeming human inhabitants, and to their servants, the lower animals ; and in cities the aggregation of population is such that, without attention to sanitary science and its teachings, existence would be well nigh impossible. It is to be carefully remembered that the great principles of hygiene are attained through obedience to Nature, and that each act of obedience makes the next easier, till, through perfect obedience, we become the controllers of all Nature's actions. The nomadic conditions of earlier ages, wherein the waste matters of the lungs, the skin, the kidneys, and the bowels of the animal inhabitants of the earth, were so distributed in a natural manner as to form the necessary food of the vegetable world, have passed away never to return. Conditions have been created wherein these waste matters of animal life, which, if not disposed of, are fatal to animal existence, have been produced in such amount within a limited space as to be far in excess of possible disposal by the

natural functions of the plant life adjacently available. Man, therefore, has had to learn in such matters "to adapt his surroundings to himself," and he has been enabled to do so only by the aid of the teaching of this same sanitary science, which it is the aim of this text-book to explain. It is a singular and suggestive fact that sanitary science in its present-day development may be epitomized as that knowledge whereby we are enabled so to adapt the conditions arising from continued residence on one spot, and from the crowding together, which is inevitable in modern urban life, in such a way that the wastes, poisonous to many, so arising are harmlessly distributed, so as to be available as the necessary food for other forms of life, and in this way be again transformed and rendered available for human use. The natural cycle is thus restored, as in the earlier ages of more scattered habitations, but restored, be it observed, only by the aid of those sanitary laws which have thus enabled man to adapt his surroundings to himself. It will thus be seen that our subject, necessarily, covers a wide field, bearing as it does on almost every surrounding and function of human existence, and within the limits of a text-book such as this it will be impossible to do more than merely outline and suggest. This we propose to do under the following general heads, viz.:—Meteorology and Site, Water Supply, Buildings, Air, Light, Food, Sewerage, Parasites and Saprophytes, Specific Diseases, Prevention of Disease, Disinfection and Sanitary Law.

"The mills of God grind slowly, but they grind exceeding small," and so Nature evolves its teaching slowly, but does not overlook the smallest matter, so that if man fails to obey her laws, disaster will surely follow. Sanitary science consists of facts and truths which are to be applied in a common-sense manner. "For science is only an estimable piece of furniture for a man's upper chamber, if he has common sense on the floor below."

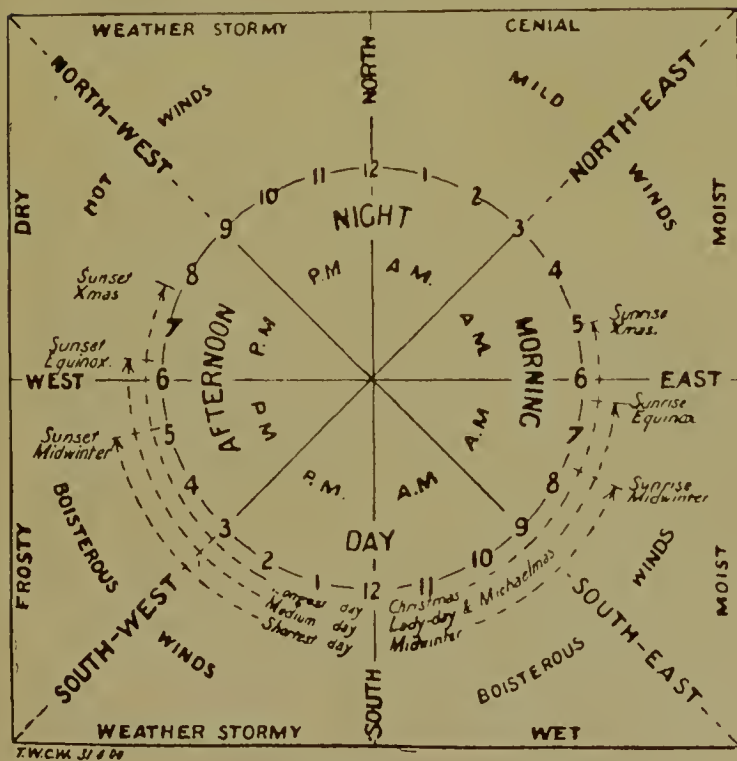
CHAPTER II.

[In this chapter it is proposed to deal with those local Conditions of Site, and with the principal Climatic Phenomena of Temperature of the Air, Pressure of the Air, Moisture in the Air, Ozone in the Air, Rainfall, Sunshine, etc]

Aspect.—With the gradual growth of civilisation dwellings assumed a character more in accordance with decency and morals, and the element of health was introduced. In arranging a dwelling due provision must be made against climatic changes, and for protection against the ill effects of winds. The direction of the prevailing winds can frequently be detected by observing the way in which the trees in the neighbourhood are grown, for the side on which the wind impinges shows the most damage and destruction. Although a site should be protected by shelter against the action of the inclement winds, still such shelter should be at a sufficient distance to prevent stagnation of air and damp. Every house should have, both front and rear, an open space *at least* equal in length to the height of the building, so as to allow of sufficient light and ventilation for the rooms on the lowest floor. The bottom of a ravine is a most unsuitable place for a dwelling, for there will be a predisposition to epidemic disease. Rising ground is always the best site, for it is never exposed to the full intensity of cold, but there must not be too great a slope as that also would cause stagnation of air. In any dwelling it is necessary to ensure that each room shall have a proper share of sunlight during the day, for sunlight is a powerful germicide and promotes the vitality of the human being. The proper admission of sunlight also prevents collections of dirt which may vitiate the

CHART OF ASPECTS AND SEASONS IN NEW SOUTH WALES.

FIG. 1.



— ASPECT COMPASS —

air, for Tyndall has shown that—"It is not the air, but something which is in the air, viz., germs, or minute forms of life, invisible to the naked eye under ordinary conditions, but which are known to form part of the vibrating motes, to which a ray of light passing through a darkened chamber owes its visibility." Elevated positions are generally healthy, but when these positions are exposed to wind blowing over marshes or malarial ground, their very elevation is a source of danger.

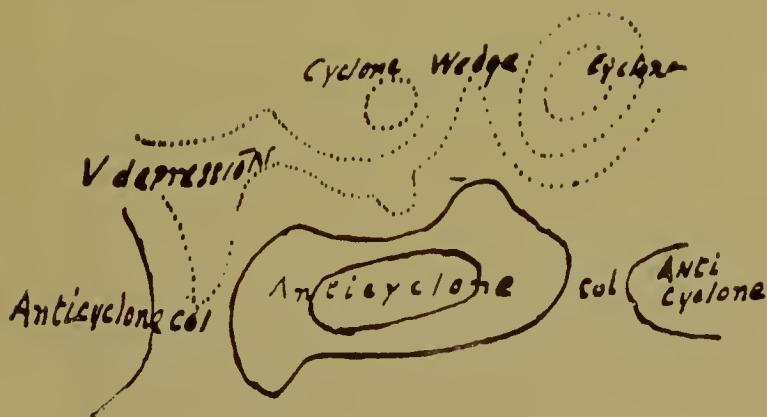
Site.—Lord Bacon has said that, "He who chooseth an ill site committeth himself unto a prison." In choosing a site for a dwelling, avoid, if possible, a clay soil, as it is cold, impervious, and the air over it is always moister than it is over dry sand. Almost every natural soil needs some precaution before it can be regarded as fit to afford a thoroughly wholesome site for a house. A porous sub-soil, not encumbered with vegetation, which has a good fall of drainage, does not receive or retain any water from any higher ground, and on which the prevailing winds do not blow over any marshy or unwholesome ground, will, as a general rule, afford the greatest amount of protection from disease which the climate admits of. Made soil is to be avoided, especially soil composed of house garbage and street refuse, for, from such abominable heaps, poisonous vapours are exhaled into the atmosphere and make evident those gross evidences of the evils of garbage tips, by disseminating miasmatic diseases, which are mere expressions of insanitary times and can largely be prevented. To sum up, therefore, the conditions of a good site are—(1) a healthy local climate; (2) a dry porous soil; (3) protection by shelter from prevailing winds, such shelter to be at a sufficient distance to prevent stagnation of air or damp; (4) the ground should fall so as to facilitate drainage in all directions - it should not be on a steep slope, and the natural drainage outlets should be sufficient and available; (5) there should be nothing to prevent

free circulation of air; (6) there should be no nuisance in the vicinity; (7) it should be always possible to effectually remove water from under all buildings and the ground in the vicinity. It must be remembered that a porous soil is very easily contaminated, and that it would be just as healthy, indeed probably healthier, to live over a pig sty, than over a site in which refuse has been buried, or over soil filled with decaying organic matter.

Winds.—In choosing a site it is important to study the direction of the prevailing winds, and to take such measures as may be necessary to prevent any damage or discomfort arising from exposure of a building to any wind which may be strong and piercing. If the readings of the barometer at any given moment at several stations over a wide area are recorded upon a map, and lines are drawn connecting all the points where the same pressure prevails, we obtain a synoptic chart of isobars. Cyclones are formed by concentric isobars, the lowest pressure being in the centre. Anti-cyclones are formed by isobars which are roughly concentric, the highest pressure being in the centre. Secondary cyclones are formed of looped concentric isobars with the lowest pressure in the centre. V-shaped depressions, with lowest pressure in the interior, form angular intervals between adjoining anti-cyclones. Wedges of high pressure, highest in the interior, are inserted between two adjacent cyclones, and usually point to the north. Cols, or necks, of comparatively low pressure are found between two adjacent anti-cyclones. For reasons influenced by the earth's revolution, the direction of the wind is roughly parallel to the isobars, and conforms to Buys Ballot's Law—"that an observer standing with his back to the wind always has the lower pressure to his left and the higher pressure to the right." The rapidity of the change of atmospheric pressure forms the "barometrie gradient," to which the velocity of the wind is directly proportionate. Cyclones cover

IRREGULAR VARIATIONS OF BAROMETRIC PRESSURE.

FIG. 1A.



Isobars arranged concentrically enclosing an area of low pressure form Cyclones. Isobars arranged in a roughly concentric mannre enclosing areas of high pressure form Anticyclones. V shaped depressions are the angular intervals, with the lowest pressure in the interior; and usually form between adjoining Anticyclones. Wedge shaped Isobars usually point to the north, and indicate areas of high pressure moving along between adjacent cyclones. Cols or Necks of comparatively low pressure, generally lie between two Anticyclonic areas.

a smaller area than anti-cyclones, and are often diverted from their course by meeting a coastline or mountain chain, and their intensity may change. Cyclones are much more numerous than anti-cyclones. Australia, from the position it occupies on the margin of the trade winds, is subject to variable breezes. Partly by the direction of the mountains, and partly by the friction of the north-west trade wind overhead, the sea breeze is usually deflected from its easterly or south-easterly direction to a north-easterly, where it blows with anti-cyclonic conditions. "As a general rule, weather is set fine when anti-cyclones move rapidly and in a straight line across Australia. And weather is unsettled when they move slowly and not in a straight line. When anti-cyclones move in low latitudes the conditions favour dry weather; in high latitudes, wet weather, especially if they rest for a time south of South Australia. One of the best marked features of Australian weather is the steady easterly progression of all the types, and the governing type, about which all other types seem to congregate, is the anti-cyclone. The normal circulation about an anti-cyclone bring southerly winds in front of them and northerly winds in the rear; hence our cold and our hot winds. Monsoonal depressions, or tongues, may occur at any time of the year, but particularly between the months of September and April, and most frequently during January, February, and March. The depression may intensify during its passage across Australia, but shows a preference to do so after it has crossed Central Australia; a fact which suggests that the heated interior has at least some influence in their development. Cyclonic storms may develop out of a monsoonal depression, and such storms frequently develop in south-east Queensland. The development of cyclonic storms from monsoonal depressions is generally heralded by the strong easterly gales on the south-east coast of South Australia and the south coast of Victoria.

Cyclones are well known on the northern coast of Western Australia. South-east gales are peculiar to the east coast of Australia. The warning of their coming is usually very short. The winter anti-cyclone is much more extensive than the summer one; it affects the mainland of Australia, and gives us our westerly winds, which follow the general move of the weather systems northwards, and thus add force to the westerly circulation of the anti-cyclone. On the east coast they extend further north than they do inland, and at times include Brisbane within their influence." Once or twice a year a tropical hurricane comes on to the coast from the eastward, but very seldom comes south as far as Sydney before it disappears to the eastward again. In Sydney, from October to March, with barometer at 30 inches, we have fresh north-east winds during the day. They generally begin between 8 and 10 a.m. in the forenoon, and gradually increase to their maximum about 4 p.m., and die away about sunset. Occasionally they last till 10 or 11 p.m., and in some cases all night, continuing night and day for several days. The barometer then falls rapidly for one or more days, and the wind changes to the opposite quarter, south-west. If north-east wind is very strong the change to the south-west will be all the more sudden, and it will blow hard from that quarter also. These gales occur nearly always in January, and occasionally in December. "Sometimes on the coast about Sydney a very strong and persistent north-east gale blows day and night for about two days; it has been known to last five days and nights, when the black north-easter ends with the advent of a southerly burster." When the wind is north-east and the barometer falls gradually, it will veer to north-north-west and west, where it will blow for one or more days. As the barometer rises it will veer to the south, and die at south-east or east, with a high barometer, to begin another circle from north-east. If in fine hot weather (north-east) the barometer

falls fast in the forenoon a southerly wind may be expected before night ; if the day is very hot it will come sooner ; and if the barometer is falling very fast and clouds are seen in the west a thunderstorm may be expected in the afternoon. "The climatic conditions preceding a southerly burster are a period of high temperature varying from three hours to three or more days, accompanied, in the early part of summer or towards its close, by wind from the west or north-west, and in the midsummer months generally from north-east." "The weather prevailing locally presents exactly the same features as that which heralds the southerly burster. An approaching anti-cyclone may be so modified locally that we have a south-east gale instead of a southerly wind ; or the southerly wind may be robbed of its velocity by rainfall on the coast of Western Australia. In Western and South Australia the weather is somewhat similar to that experienced in New South Wales, and the burster is felt in South Australia and Victoria." These storms are attended with strong electrical excitement, and sometimes lower the temperature 20deg. in a quarter of an hour. In autumn the wind begins to change to westerly and brings unsettled weather. The winds from north and south-west are dry winds, warm in summer and cool in winter. Easterly winds are humid, being in summer cool and in winter mild ; but owing to moisture in excess sometimes in winter become intolerably chilly, and in summer give rise to the muggy days which are so oppressive and unhealthy in New South Wales. Southerly winds are in most cases dry, but in storms often bring rain.

Temperature.—A climate may be torrid, hot, temperate or cold. It is torrid when it lies between the isothermal line 80deg. Fahr. and the thermal equator. It is hot when it lies between the isotherm 80deg. Fahr. and the isotherm 60deg. Fahr. It is temperate when it lies between the isotherm 60deg. Fahr. and the isotherm 40deg. Fahr. It is cold when

it lies between the isotherm 40deg. Fahr. and the isotherm 24deg. Fahr. Although the temperature decreases with the altitude of a district above the sea, the decrease is subject to many variations dependent upon latitude, situation, dampness and dryness of atmosphere, upon surroundings, season of year, and hour of day. The temperature of any locality is lowered 1deg. for every 300ft. of altitude above the sea. It is also lowered 1deg. for every degree of latitude; but a greater variation is due to the proximity of the ocean, the temperature of which prevents an extreme degree of heat and cold in countries bordering thereon. The position of a site as compared with the level of the adjacent country affects its temperature, for when the air in contact with declivities of hills and rising ground becomes cooled by the ground the cold air will flow over the sides of the hills into the valleys, displacing the warmer air and forming, as it were, pools of cold air. Sydney, New South Wales, in latitude 34deg., has a summer temperature only four degrees warmer than that of Paris, which is in latitude 49deg. Reckoning by the usual difference of a degree for each degree of latitude, Sydney should be at least 15deg. warmer than Paris; but this is not so, and the highest shade temperature, 108·5deg. Fahr., registered in Sydney is only 2deg. higher than the highest shade temperature, 106·5deg. Fahr., registered near Paris. One of the principal dangers to health in torrid and hot countries lies in the fact that the conditions of heat and moisture are such that they favour the putrefactive process, and the decomposition of animal and vegetable matter. For instance, in the climate of Sydney, under certain conditions, even fresh slop water has been found to become offensive from putrefactive change within twelve hours; and in ordinary summer weather such change will in most cases occur in twenty-four hours. In this way poisons are produced during the putrefaction of albuminous compounds, and become introduced into the blood

system and give rise to disease. A high range of mean temperature, therefore, is an important element in tropical and sub-tropical climates ; but although a tropical climate is credited with having a devitalising influence, with shortening the duration of life and weakening the constitution, still Lane Notter points out that " these evils are due to causes other than those of climate, and that by restraint in the indulgence in alcoholic drinks, by regulation of the amount of animal food, and by simple hygienic precautions, the deadly effects attributed to climate have disappeared." In temperate and cold latitudes the conditions of decomposition are not so intense, and where they exist they are more easily controlled.

Rainfall is stated in inches and points. This means that if, for instance, a vessel with a flat bottom and vertical sides, such as a kerosene tin, is set on the ground, a rainfall of 6 inches and 40 points would fill it up to a depth of 6 inches and 40-100ths of an inch. That is to say that the rain which fell over the area of the top of the kerosene tin was equal in depth on the same area of ground to 6 inches 40-100ths of an inch. In making such a test, care must be taken that the measuring vessel has vertical sides, as otherwise the area of the open top into which the rain fell, and of the bottom where it collected, not being the same, the depth of collected rainfall would not be the true depth of rainfall. The annual rainfall in England varies from 20 inches to 70 inches, the average being 40 inches. The greatest rainfall in England in twenty-four hours equals 3 inches, and the greatest rainfall in one hour equals 1 inch. The rainfall along the coast lines of New South Wales is very abundant, and ranges from 48 inches in the South to 76 inches in the North. At Sydney it is 50 inches. Along the tops of the mountains the rainfall is from 30 to 40 inches, on the western slopes from 20 to 30 inches, and over the flat country from 10 to 20 inches. The coast rains are often tropical in their character, and deposit water in such abundance upon

the face of the mountains as to feed many rivers. Years pass, however, between two such visitations. The rain in New South Wales is heavy compared with that of England—that is, when falling, much more falls per hour. Sydney in 148 days has 49·80 inches of rain, while London has only 24·76 inches in 146 days. The heaviest shower in New South Wales has been at the rate of 6 inches per hour, lasting for from 10 to 15 minutes. Rain varies greatly, both in frequency and rate of fall. The average of a rainfall gives a wrong impression of different parts of the country. As a rule, the rainfall is the parent of the ground water, and the engineer should not look to the average of a series of years, but to the maximum and minimum fall. Rainfall plays a most important part in the purification of the air, and it is looked upon as probable that the friction of the water drops, as they fall as rain against the air, produces electricity, which, acting on the oxygen of the air, gives rise to ozone.

Practical Applications.—The practical application of these matters of aspect, environment, winds, temperature, and rainfall, to the work of the sanitary inspector, can better now be explained after the general principles and facts have been assimilated. Without an understanding of their underlying conditions, practical application would be limited to a mere series of isolated examples lacking the key to their causation; but with such understanding we are enabled to bring cause and effect into close relationship, and are so prepared to judge as to healthful conditions.

Humidity.—The importance of humidity in relation to temperature and winds as a factor affecting our daily life can hardly be over-estimated. In this connection humidity is of importance, mainly because of its influence on the evaporation of water as affecting the elimination of moisture from the skin and the temperature of our surroundings, and this influence is materially affected by the velocity of

the air currents, while "temperature" affects the matter because of the *sensation* of chilling, cold or oppressive heat arising under varying combinations of temperature and humidity. The humidity is commonly described as the "percentage of saturation," and it will be necessary here to explain what that expression means.

Evaporation.—Evaporation is the conversion of a liquor into a vapour, and this conversion takes place under two main conditions, and forms one of the most powerful cooling agencies in nature. These conditions are: (a) evaporation *above* what is called the boiling point; and (b) evaporation *below* the boiling point. Evaporation is commonly associated in the popular idea with the case (a), and is conceived of as being effected by raising the temperature to the boiling point; as, for instance, water boiled off to steam. This involves usually a double misconception, namely, the confusion of heat with personal sensation popularly called heat, and the limiting of the process of evaporation to the conception of boiling off.

The disappearance of pools of water in *cold*, dry weather is as truly due to evaporation as is the boiling dry of a kettle, and the evaporation in the former case requires more heat, and in point of fact more heat is actually absorbed than in the latter case, although, so far as we are concerned, the personal sensation accompanying the process is one of "cold," and not of "heat," as in the case of the boiling water.

In order to make these points clear, we must separate personal sensation, or rather we must understand what the personal sensation of heat and of cold actually mean. It is a well-known fact that if we place two bodies of differing temperatures side by side, an interchange of heat takes place; the temperature rising in the cooler body and falling in the warmer body, till the temperatures of both bodies are

the same, when no further relative change takes place. Without entering into the physics of the actual exchange which thus takes place, it is sufficient for our purpose here to realise the fact that the warmer body is losing its heat to the colder, and this is most simply realised by considering the movement as a flow of heat from the body at higher temperature to that at the lower temperature until, so to speak, the heat level is equal in both, when the flow ceases. Now the sensation of heat and of cold ; is merely dependent on the rate at which we are losing our bodily heat to our surroundings, or gaining or absorbing heat from our surroundings. If the loss is in excess we feel our surroundings to be cold, and, as the speed of the heat flow increases rapidly with differences in temperature, if our surroundings are such as to rob us of our bodily heat with abnormal rapidity, we ultimately die of cold, as the saying is. If, on the other hand, our surroundings are such that the natural dissipation of heat from our bodies is unduly checked, we feel first hot and oppressed, and if these conditions become aggravated, we die of heat ; in fact, in extreme cases, are burned to death. It thus follows that if we approach our hand to boiling water, we feel it to be warm because the heat is flowing from it to our hand, but if we bring our hand near the drying pool on a cold day we feel it to be cold because we are contributing heat to it from our bodies, and are so in a sense taking the place of the fire in the former case, and contributing part of the heat necessary for its evaporation or drying up.

Measurement of Heat.—It has been shown that an exact amount of heat is required to evaporate a given quantity of water, and it is important that this also should be clearly understood. In the first place we cannot measure the amount of heat by temperature alone ; that can give us only the degree or intensity of the heat, not its quantity. For instance,

common-sense tells us that it takes more fuel to boil a large copper full, say 40 gallons, of water, than it does to boil a small saucepan holding, say, half a pint. Yet we have raised both but to the same temperature; obviously then, temperature *alone* is *not* a *measure* of the heat required. In order to estimate this we must also consider the quantity of the substance to be heated, and the unit measure of heat is founded on this consideration.

Heat Measurement Units.—This medium of measurement varies in Britain and in France. The former, which we shall use throughout these notes, is known as the British Thermal Unit and is defined as the amount of heat required to raise 1lb weight of fresh water 1 degree in temperature by Fahrenheit's thermometer scale. The French unit or "caloric," as it is called, is the amount of heat required to raise 1 kilogramme of fresh water 1 degree in temperature by the centigrade scale. Thus, 1 caloric is equal to about 3.968 British units.

Thermometers.—The thermometer, as has already been pointed out, measures the degree or intensity of heat but not its amount. It depends for its action and indication on the change of bulk which substances undergo when their temperature is changed, the motion so-called being multiplied either by mechanical action as in the case of the unequal expansion of attached metals as in the metallic thermometers, or by enclosing a suitable liquid in a comparatively larger ball or chamber, and allowing the small expansion of the larger enclosed bulk to expend itself in a very small tube. The motion is in this way magnified so as to cause small changes of temperature to produce a visible change in the length of the liquid in the small tube. The latter form is that most commonly in use, the liquid being mercury, except when very low temperatures are to be measured, when spirits of wine are employed. It should, however, be remembered, that the spirit

thermometer is only suited for low temperatures, and the mercurial thermometers must be used for temperatures approaching and above the ordinary boiling point of water. As mercury freezes at 38 degrees below zero on Fahrenheit's scale, and boils at 660deg., it cannot be used to measure temperatures either above or below these points. The spirit is used for the lower temperatures and what are called pyrometers are made which measure the higher temperatures with a greater or less approach to accuracy.

Graduation of Thermometers.— Obviously, no matter what division of a thermometer scale is used when the liquid has been dilated to the same extent it is at the same temperature. There are three scales used, viz., Fahrenheit, Centigrade and Reaumur; but all three have two fixed points, viz., that of the freezing point and that of the ordinary boiling point of fresh water under standard conditions of pressure. The sole difference between the three scales consists in the number of divisions made between the two fixed points. In Fahrenheit's scale, which is the one most popularly used here, the freezing point is marked 32deg. and the boiling point 212deg., there being thus $212 - 32 = 180$ deg. between the two fixed points. The Centigrade scale has the freezing point marked 0deg. and the boiling point 100deg., and Reaumur freezing point 0deg. and boiling point 80deg. The Fahrenheit usually written Fahr., and the Centigrade written C., are the two scales mostly used, and in order to convert the one into the other, it is well to remember that the degrees C. are $\frac{2}{5}$ ths of those Fahr., and conversely, the degrees Fahr. are $\frac{5}{9}$ ths of those C.

The scales attached to the metallic thermometers are usually made on the basis either of the Fahr. or C. divisions.

Hygrometry.— Armed with the information above conveyed as to heat and temperature measurements

the measuring of the moisture in the air, which is known as Hygrometry, and its relation to evaporation at and below the boiling point, can now be explained.

The instrument commonly used to determine the humidity of the air depends for its indications on the cooling effect of evaporation. This effect is caused by the more or less rapid absorption of heat by the vaporising body which is water. The dryer the air the quicker the vaporising or drying action, and consequently the greater the cooling, or rather absorption of heat. It has been found that, in order to raise 1lb. weight of fresh water from zero Fah. and turn it to vapour, 1177 measures or units of heat are always absorbed. No matter at what temperature the vaporising takes place, so much of this heat goes to raise the temperature of the liquid from zero to the temperature at which the drying-up or boiling off—in short, the vaporising—take place, and this is called “sensible” heat, because it produces a rise of temperature which can be measured by the thermometer. But by far the larger quantity of this heat cannot be so measured, simply because it disappears as heat, and because it has been converted into the work of expanding the liquid to the enormously increased bulk of vapour against the pressure of the atmosphere. This changed heat is known as “latent” heat, and it is to its loss or absorption that the enormously cooling effect of evaporation is due. Thus it appears that to raise water to the ordinary boiling point of 212deg. Fah. 1lb. would require the addition of 212 units out of the above 1177, and the balance, or 965, would require to be added as heat, but would utterly disappear as far as rise of temperature is concerned. If the drying-up took place at, say, an ordinary temperature of 60deg. Fah., even more heat would disappear in this way, because in that case only 60 units out of the 1177 would be required as sensible heat to raise 1lb. of water from zero, and the balance, or $1177 - 60 = 1110$

units, would be absorbed from the surroundings and even from the water itself and so disappear. It is this enormous heat-absorbing power which largely causes the coldness and consequent unhealthiness of damp houses and damp sites. It thus appears that the quantity of water evaporation in a given time has a vital influence on the temperature of a place or district.

The quantity depends on temperature and percentage of saturation or quantity of vapour already existing in the air, and here we come to the difference in these conditions *at* and *below* the boiling point. At the boiling point the vapour has the power of entirely displacing the air, so that an atmosphere of steam contains practically no air, and therefore can support neither life nor combustion. Below the boiling point the vapour can displace only a certain proportion of the air, that proportion becoming less and less as the temperature is lowered. When, therefore, air containing no moisture is brought in contact with water it immediately begins, so to speak, to dry up that water—that is, the water evaporates into the air—and this process, rapid at first, continues more and more slowly till the water vapour has displaced the air to the extent which the particular temperature warrants. When this condition has been attained, the air is said to be saturated and further evaporation stops. If the temperature is then raised the vapour can of course still further displace the air and evaporation recommences, the air being then said to be more or less “dry.” Its condition at this point is expressed by the term “percentage of saturation,” which means the percentage of the vapour it could contain at the higher temperature which it actually does contain.

If, on the contrary, the temperature were lowered instead of raised, so much of the vapour would be condensed again to water, forming what is known as dew or rain as the case may be, and the air at the

lower temperature would of course still be fully saturated.

Hygrometers.—Hygrometers, which, as the name implies, are used for determining the condition of the air as regards the water vapour it contains, are of two types. 1st. Those whereby the percentage of moisture is determined by measuring the cooling effect of the evaporation of water, of which the ordinary type is what is known as the wet and dry bulb thermometer; and, 2nd, those wherein the temperature of the air in contact with the instrument is artificially cooled till its moisture begins to be deposited as dew, and which are known as “dew point thermometers.” Those of the first type consist essentially of two thermometers, one having its bulb covered with fine muslin, kept constantly moist by means of a wick dipped in water, and the other exposed to the air without any moist covering. By means of special tables the difference between the wet and dry bulbs, together with the temperature of the dry bulb, furnishes the data necessary to determine the percentage of saturation, and incidentally the temperature of the wet bulb as compared to the dry bulb shows directly the cooling effect of a moist surface under the particular hygrometrical conditions existing at the time. Dew point thermometers consist essentially of a thermometer having the bulb enclosed in a casing either of polished metal or of gilded or mirror glass. By means of suitable arrangements (usually consisting of some means for lowering the temperature by the rapid evaporation of some volatile liquid such as ether or gasoline) the temperature of the thermometer and its bright casing is gradually lowered until a perceptible dew is deposited on the bright surface, and the thermometer then indicates the temperature at which this deposit takes place—*i.e.*, the dew point, of temperature at which the moisture existing in the air fully saturates it. By means of tables giving the weight of moisture the air can contain at different

temperatures, the weight of moisture the air actually does contain as indicated by the dew temperature can be compared with the amount it could contain at its actual temperature as indicated by an ordinary thermometer and its percentage of saturation so determined.

The influence of various degrees of saturation on health and comfort and the use of these instruments in sanitary inspections will be dealt with in the chapter on air ventilation.

Barometer.—The barometer, whereby the pressure of the atmosphere is measured, is not of such direct importance in sanitary work as the hygrometer. It is, however, of use in determining the practical lift of ordinary pumps, because the principle on which the barometer works is the same as that which enables water to be raised from a well by the ordinary lift pump. The barometer is essentially a very delicate pair of scales, whereby the pressure of the air is determined by ascertaining the height of a column of mercury, the weight of which exactly balances the pressure of the air. This is done by entirely removing the pressure of the air from the surface of the mercury within the barometer tube and allowing the air to press on the exposed surface of the mercury outside the tube. By this means the air pressure pushes the mercury up the tube until the weight of the mercury balances the pressure of the air, when the scales, so to speak, come to rest. It has been found that at the sea level the air pressure is such that it balances in this way a column of mercury nearly 30 inches high, which corresponds to a pressure of about 15lbs. on each square inch of surface.

Effect of Elevation.—The pressure of the air diminishes as we ascend above the sea level, but not regularly. It will, however, be of use to remember that it diminishes roughly 1 inch or 1-30th of the whole pressure for every 900 to 1000 feet of elevation.

If, therefore, we deduct 1-30th from the safe lift of an ordinary pump for every 1000 feet of elevation above the sea level it will be a safe allowance.

The height to which an ordinary well-proportioned lift-pump will raise fresh water freely at the sea level may be taken at about 28ft., and this should be diminished as above stated about 1-30th for every 1000 ft. rise. If wells are deeper than this, the pump must be placed down sufficiently far into the water, and what is called a lift and force pump used.

A barometer may be mercurial, glycerine, water, or aneroid. The mercurial barometer consists of a tube 33 inches long, closed at one end and open at the other. This tube is filled with mercury and placed vertically with the open end dipping into a cup of mercury, this cup being called the cistern. The mercury in the tube therefore falls with lessened pressure of air, and rises with increased pressure. The level of the mercury surface in the cistern varies with every change of pressure, and consequently the zero end of the scale which marks the height of the vertical column has to be adjusted to the mercury surface of the cistern. To overcome any error which might arise, a capacity correction is noted and recorded on the scale to state the ratio of the interior area of the tube to that of the cistern. The capacity correction is applied by taking the indicated fractional part of the difference between the height read off and that of the neutral point, and adding or subtracting it from the reading, as the case may be. The neutral point is a certain height of the column, which is correctly measured by the scale. When the mercury sinks below this, the height read off will be too great, because the level of the mercury in the cistern will have risen above the zero in the proportionate amount. In the Kew barometers the error is obviated by graduating the scale in nominal inches from above downwards, in proportion to the relative size of the diameter of the tube and cistern.

These inches are shorter than true inches, the highest point on the scale being marked off correctly from a definite point on the cistern side. In the Fortin or standard barometer the capacity correction is avoided by giving the cistern a pliable base of leather, capable of being raised or lowered by means of a screw. The upper part of the cistern is made of glass, through which the zero of the scale can be seen on a piece of ivory, whose lower extremity is called the fiducial point. To take a reading, the level in the mercury in the cistern must be exactly at this point. The aneroid barometer is an air-tight metal box from which the air has been displaced by peroxide of hydrogen, and so constructed that as the atmospheric pressure rises, so the metal box is forced in, and helped by means of a strong spring, bulges out again when the pressure lessens. An arrangement of levers regulates the turning of the index hand on the dial, and motion of the sides of the box to an extent of $1\frac{22}{100}$ ths in., causes the index to move through 3 in. of the dial plate. These barometers are very sensitive and convenient, but liable at times to go hopelessly wrong. The cases and scales of all good barometers are made of brass, because the co-efficient of its expansion by heat is well-known. In all standard barometers we have two scales: one fixed and the other the movable Vernier. Each long line of the fixed scale is 0.1 in., and each short line is .05 in. The Vernier scale is marked off in such a manner that 25 of its divisions are equal to 24 half tenth divisions on the fixed scale. To take a reading of a barometer, note first the temperature, adjust the level of the mercury in the cistern, place the Vernier scale so that its lowest edge is level with the top of mercurial column. One of the marks of the Vernier scale must coincide exactly with one on the fixed scale. A barometer must have its tube properly calibrated or corrected for capillarity, and also have the index error properly noted. Proper tables have been worked out for corrections for temperature,

which, according to Schumacher, are resolved by the following formula : —

h = observed height of barometer in inches

t = temperature of attached Fahrenheit thermometer

m = expansion of mercury per degree, viz., 0·0001001 of its length at 32deg. Fah.

s = linear expansion of scale, viz., 0·00001041 at 62deg. Fah.

$$\frac{-h m (t - 32\text{deg.}) - s (t - 62\text{deg.})}{1 + m (t - 32\text{deg.})}$$

As mercury expands $\frac{1}{9990}$ th of its bulk for each degree Fah., multiply the number of degrees above 32 deg. by the observed height and divide by 9990 ; subtract this quotient from the observed height ; or multiply the number of degrees below 32deg. by the observed height, divide by 9990, and add this to the observed height.

To measure a height by the barometer, read to the nearest hundredth of an inch ; subtract the upper reading from the lower, neglect the decimal point, and multiply the difference by 9 ; the product is the elevation in feet.

SOIL.

By the term soil is meant all the portion of the earth's crust, which by any property or condition can affect health. Since the chief origin of the surface layers of the ground is from the gradual disintegration of rocks, the nature and composition of a soil in any given place will greatly vary, according to the geological history of the locality. Changes of temperature, largely aided by frost, have cracked and broken up these various rocks mechanically, and the external surfaces of the rocks have become weathered. The

formation of the surface soil from the weathering and decomposition of rocks, is by no means a purely chemical process caused by the direct action of the rain and air, but is also in large part aided by the presence and action of both animal and vegetable life. The constitution, therefore, of the soil has an important bearing upon the health of any locality, for being partly composed of the inorganic matter derived from the subsoil, and partly of the products of decomposition of animal and vegetable matter, soils are only healthy when kept entirely free from sewage and decaying organic matter, for pathogenic germs may lie dormant in soil for years, and may be roused into activity when the soil is disturbed. Soils have capacity for retaining and giving off heat, and certain soils are warmer than others. There is a marked difference in the manner in which the surface soil temperatures follow the variations in atmospheric heat as compared with the temperatures of the deeper layers. The daily changes of atmospheric temperature do not affect the temperature of the soil to a greater depth than 3ft., and at greater depths it ceases to be perceptible. The annual variation is not of any importance below 6ft., and the mean temperature of the soil follows very slowly the mean temperature of the air. For all practical purposes, the temperature of the soil, after a depth of 6ft. to 8ft., may be said to be fixed all the year round. In a general way it may be said that at a certain depth below the surface the temperature is constant at the mean annual temperature of the district. This depth varies according to the extremes of surface temperature. In the tropics it is about 3ft. down; here, in Australia, from the results obtained by Mr. H. C. Russell, with thermometer reaching 19ft. below the surface, it is probably 26ft. to 30ft.; and in countries like Canada it is probably deeper. Mr. Russell's experiments on the subject, are of much value, as showing the earth temperatures' influence on the ventilation of rooms and the cooling

EARTH THERMOMETERS, SYDNEY OBSERVATORY.

In the Ground.	19 feet.			10 feet.			5 feet.			2 feet 6 inches.			1 inch.			Temperature in Thermometer Shed.		
	Mean.	Max.	Min.	Range.	Mean.	Max.	Min.	Range.	Mean.	Max.	Min.	Range.	Mean.	Max.	Min.	Range.	Mean.	Max.
1887.																		
January.....	66.1	67.0	65.1	1.9	67.5	68.7	66.0	2.7	69.7	70.7	67.8	2.9	71.2	74.5
February.....	67.3	68.0	66.8	1.2	68.5	69.2	68.0	1.2	70.1	71.0	69.0	2.0	69.7	73.2
March.....	67.8	68.1	67.3	0.8	69.3	69.5	66.0	0.5	70.8	71.8	69.5	2.3	70.7	73.6
April.....	67.6	68.2	66.8	1.4	68.2	69.3	66.5	2.8	68.0	70.4	65.3	5.1	65.9	72.8
May.....	65.4	66.8	63.0	3.8	64.7	66.4	62.3	4.1	62.7	66.0	60.4	5.6	58.6	64.7
June.....	62.5	64.0	61.3	2.7	60.8	62.8	59.3	3.5	58.4	60.7	56.5	4.2	54.1	60.0
July.....	60.5	61.6	59.7	1.9	58.6	59.2	58.2	1.0	56.9	57.5	55.8	1.7	53.9	57.6
August.....	59.6	60.0	59.1	0.9	58.4	58.7	58.0	0.7	57.5	58.5	56.7	1.8	55.0	58.3
September.....	59.6	60.1	59.1	1.0	59.0	60.7	58.5	2.2	55.3	59.9	57.4	2.5	56.2	59.7
October.....	60.8	61.8	60.1	1.7	61.1	62.6	60.0	2.6	62.9	64.1	59.9	4.2	62.0	67.5
November.....	62.2	63.1	61.6	1.5	62.6	63.3	62.0	1.3	62.8	65.2	61.0	4.2	62.4	67.5
December.....	63.6	64.4	62.6	1.8	66.4	65.3	62.8	2.5	65.6	67.4	63.8	3.6	66.4	71.0
Means.....	63.6	..	..	..	63.8	..	..	..	62.2	..	..	..	62.8	..
In the year—Extremes.....	68.2	59.1	9.1	..	69.5	58.0	11.5	..	74.5	50.8	23.7	..	94.3
1886.....	65.8	68.2	63.7	4.5	64.0	67.9	59.8	8.1	64.1	69.7	57.8	11.9	64.3	71.8	56.0	15.8	62.7	74.0
1885.....	65.0	66.8	63.2	3.6	63.6	67.8	58.8	9.0	63.9	69.0	57.2	11.8	64.2	71.5	54.8	16.7	63.2	74.0

effect of cellars in summer, and for that reason may be quoted here.

In regard to these results, Mr. Russell points out the very great influence of even a few inches of soil, especially if the surface be shaded. Further, the cooling effect of the increased evaporation from a grass surface considerably assists in the cooling action, especially in hot, dry weather. The determination of the earth temperatures below the zone of equal annual temperature is less important to sanitary inspectors, but to those interested in the subject reference may be had to the very interesting series of observations made in the course of sinking of the deep shafts of the Sydney Harbour Collieries. It should be noted that Mr. Russell has pointed out that after the earth thermometers at the Sydney Observatory were placed in position it was a considerable time before the indications became normal, the disturbance of the ground caused by the excavation of the shaft to receive the thermometers having evidently set up disturbing conditions which took some time to readjust themselves. This is important to note in making future tests of this kind. The temperature of the earth increases with the depth, but this rate of increase of temperature varies in different geological formations. Whilst the mean temperature of the ground depends upon the climate, soils have a very varying capacity for both absorbing and giving off heat, and the conducting capacity of the soil has an important bearing on the comfort, if not upon the health, of those who live upon it. Schubler's observations show that if the power of retaining heat is assumed at the standard of 100—

RELATIVE POWER OF SOILS TO RETAIN HEAT:

Sand with some lime	... 100	Gypsum	.. 72.2	Pure Clay	... 66.7
Pure Sand	... 95.6	Heavy Clay	71.1	Fine Chalk	... 6.8
Light Clay	... 76.9	Clayey Earth	68.4	Humours	... 49.8

The sands, therefore, have the greatest power of retaining heat, while the clays are comparatively

cold. The presence of organic matter in any soil causes it to possess a relatively greater power of absorbing heat. The rapidity with which soils radiate and absorb heat depends somewhat on their colour, and the kind and thickness of the vegetation growing upon them. Vegetation has a very important action on the temperature of the soil, and regulates the amount of radiation and absorption of heat. In fact, the absorption of heat is determined mainly by the nature of the soil and the presence or absence of vegetation ; but the rapidity with which soils radiate heat is not necessarily equal to their power of absorbing it, in fact, the former process is usually greater than the latter. Trees are useful in that they attract moisture, but if they are too thickly placed they obstruct the sun's rays, they impede the current of air, and they abstract too much moisture from the soil. The hottest and driest places in the tropics are those divested of trees. Herbage is always healthy, and nothing is more desirable than to cover, if it be possible, the hot sandy plains of the tropics with close-cut grass. Forest may act in the same way as a range of hills, to increase the rainfall in summer by causing condensation in the case of warm, moist winds.

The net result of trees and shrubs is to render the ground cool and moist in winter, and cool and dry in summer when the leaves are out. Brushwood is frequently bad. Grass, like trees, renders the soil drier, cooler, and more equable in temperature, for it lessens the absorption of the heat by the soil, and also the true radiation, but it increases the evaporation and conversion owing to the vast surface of the blades of grass. According to Everett, the heat of the earth's surface is not influenced by the flow of heat from below upwards, and at greater depths than 34 feet or so the heat of the earth, or temperature gradient, causes a rise of 1deg. Fah for every 55 feet, or the soil heat gradient is five times steeper than that of air. Healthiness of the soil is

in a great measure governed by the relation which the air in the soil bears to the water contained by it, and this moisture depends upon the amount of and mode of incidence of the rainfall and the facilities for its removal. In the permeable soil below the surface, the interstices are full of water to the exclusion of air, so that, except in so far as its particles are separated by the solid portions of the soil there is a continuity of water. This ground water is a continuous sheet extending downwards to the next impermeable stratum. The surface of the ground water is not necessarily horizontal, but follows the line of impermeable stratum which may by its nearness bring the water close to the surface of the soil. This subsoil water flows to the nearest water-course with a velocity which varies with the permeability of the soil, the steepness of the gradient, and the absence of the obstruction by roots of trees. Sometimes the range of the rise and fall does not exceed a few inches, but it is not more usually several feet. The level of the ground water is affected by the percolation of the rainfall, and this percolation is greatest after a wet period, when the soil becomes saturated. Sand allows the greatest amount of percolation, and the proportion of percolation in different soils varies with the time of the year, the quality of the soil, its capacity for heat, and the character and extent of the vegetation with which it is covered. The power of retention of water in soils, by the planting of trees, was well exemplified in the Island of Ascension, which was formerly a barren rock. After trees had been planted on the island it began to be able to retain the rain which fell, and is now a watering place for the ships of the Royal Navy. Soils may retain water through their permeability, through imbibition and through saturation. Absorption being mainly dependent upon capillary attraction, is always greater for rocks or soils which consist of fine particles. Pure sand will hold 40 to 50 gallons of

water per cubic yard, or about 17 per cent. of its weight when dry, but the condition of two localities vary greatly, although there may be an apparent general similarity of the soils. The soil above the level of the ground water may be kept moist either by evaporation from below or by capillary attraction. All rocks are to some extent permeable and, therefore, are capable of containing water. A cubic yard of granite or marble holds about a pint of water, of sandstone 25 gallons, and of sand 50 gallons.

Soils may also absorb and retain moisture from the atmosphere, and it has been found that the power to absorb water in this way and to retain it, however it may have been absorbed, is dependent very largely on the proportion of vegetable matter and also alkalies in it.

Soils vary so greatly on these points that the only way of arriving at an exact result in any case is to make a test. This is done by taking a section of the soil, drying it thoroughly in an oven, taking care not to char it; then fill the dry soil into a glass tube about an inch in diameter and (say) two feet long. Weigh the tube and earth carefully, and then place it vertically with the bottom dipping into a saucer of water. The section of soil will in this way absorb water by capillary attraction and evaporation, and also from the atmosphere to the extent of its capacity, and on weighing after two or three days' exposure will give the proportion absorbed.

The hardest rocks are alone perfectly free from ground air, and all soils contain both air and water. The subterranean atmosphere, which is chiefly confined to the surface layers of the soil, is in continual movement, and this movement is affected by the temperature of the earth and the fluctuations of the level of the subsoil water. Fluctuations of the level of this water of course cause increased movement of the ground air, so that large quantities are slowly either poured out from or drawn into the soil. The ground air varies in volume according to the porosity

and other conditions of the soil. It usually contains moisture, organic matter of vegetable or animal origin, sometimes ammonia, sulphuretted hydrogen, and marsh gas, and is always very rich in carbonic acid. Pettenkofer, who first pointed out the excess of carbonic acid in ground air, is also of opinion that the amount increases with the depth from which the air is drawn, and it has been discovered that just as the carbonic acid increases, so does the amount of oxygen decrease with the depth at which the soil air is drawn.

The capacity of soils and rocks to hold air is measured conveniently for our purpose by ascertaining the quantity of water they can absorb. In this way a quantity of the soil or rock is first weighed in its natural condition, then it is placed in a vessel and gradually covered with water filled in slowly from the bottom; and then the water is allowed to drain off, and the soil again weighed. Finally, the sub-water soil is placed in an oven and thoroughly dried and again weighed. The last, of course, gives the weight of the dry soil, and the other two weighings respectively the percentage of water in the soil as obtained and the maximum amount of water it can contain. Keeping in remembrance that 1 gallon of fresh water measures $\cdot 16$ cubic feet and weighs 10 lbs. avoirdupois, it becomes an easy matter to calculate the bulk represented by the water, and hence the air it can contain when the water is withdrawn. This method is not, however, applicable to clays, which contract in drying, so that the water absorbed is no measure of the air-capacity, which in clays is very small. Now, as this ground air continually passes in and out of the ground, through being displaced by certain conditions, it is important that the soil should be kept as free as possible from water and organic impurities. Wind, variations in temperatures, variations in barometric pressure, and rise and fall of the subsoil water, all combine to keep the ground air in constant movement. Loose

sand may contain 50 per cent. of its volume of air; soft sandstones, 20 to 40 per cent. The mineral constituents of soil are of the utmost variety, and need not be considered in a work of this nature. Soil consists also of organic matter, which it receives through pollution. Soil may be polluted by animal or vegetable matter, and around the vicinity of buildings it is ignorantly, criminally, but unintentionally polluted on an enormous scale. In past days, and even now, it has been the custom to raise the surface of the soil by filling up the hollows and low-lying sites with house garbage and street refuse. Such a practice in forming the artificially made soil is fraught with danger, for the impurities only very slowly disappear, unless there is free exposure to air and a free outlet for drainage to accelerate the process of purification.

Until soil, impregnated with decaying matter, has been freely opened and oxygenised, it is in the highest degree deleterious to health.

Nitrification.—The mere presence of organic matter in the soil does not necessarily indicate danger to the neighbourhood, because, supposing the soil to be of a porous nature, and in free contact with air, the organic matter is quickly oxidised into innocent compounds. This process of nitrification takes place in the upper layers of the soil to a depth of three or four feet. It is a fermentative process, and is excited and carried on through the agency of minute organisms or microbes, the growth of which has the result of resolving highly complex organic compounds into soluble salts or gaseous bodies. The nitrogenous organic matter contained in the soil is to some extent oxidised by filtration, with formation of nitrites, but the principal action is brought about by means of certain micrococci and bacilli, called saprophytes, which convert the nitrogen of organic matter into ammonia and nitrites, and also prevent the propagation of pathogenic organisms near the surface of the

soil. It is possible, however, to overload any soil even when it oxidises rapidly, and to have more organic matter present than, under existing circumstances, admits of oxidation in a certain time. When any soil is overloaded beyond its powers of nitrification, putrefaction is the result; and, consequently, any "made soil" is to be looked upon with suspicion, and is usually impure and unfit for a building site. It is well known that in a thoroughly soaked sewage-sodden soil, to which little air can have access, nitrification does not take place, and hordes of pathogenic micro-organisms may be produced and become disseminated through the soil by upward diffusion. The subsoil of all cities of any magnitude or of any great age has become sewage sodden, through ignorance, and the too-close proximity of dwellings. So long as we continue to pollute the porous soils of the sites of our towns, so long must we expect disease to make havoc amongst us. The effect of barbarous municipal muck-heaps is very marked, and the germs of virulent blood-poisoning are contained in the putrilage owing to the putrefaction of animal and vegetable matter. The experiments of Drs. Robertson and Sidney Martin show the dangers arising from contaminated soil, and how that any pathogenic germs which may happen to be in the soil have a tendency to diffuse through the soil in an upward direction, and to pass into the atmosphere. Surface soils are the most likely to become contaminated by pathogenic organisms, and to retain a large number of them in its upper layers. Consequently all soils should be provided with a free drainage.

The unhealthiness of houses built upon "made soils" for some time after the soils are laid down, is no doubt to be attributed to the constant ascent of impure air, from impure soil, into the warm houses above, and a house artificially warmed must be continually fed with air from the ground below, and doubtless this air may be drawn from great depths.

Telluric Diseases.—Pathogenic organisms are known to be able to live and multiply in the soil. Telluric conditions affect such diseases as anthrax, tetanus, malaria, enteric fever, cholera, diarrhœa, and yellow fever. Enteric fever has, in certain localities, a known relation to the fluctuations of the level of the ground water, and Pettenkofer, of Munich, has come to the conclusion that the conditions necessary for an outbreak of enteric fever are : A rapid fall (after a rise) of the ground water, pollution of the soil with animal impurities, a certain earth temperature, and the presence of a specific organism in the soil.

There can be no doubt that although no pronounced relation has been found between the death-rate or prevalence of typhoid fever and the temperature or putrefactive activity of the soil, still a contaminated soil, throughout which foul matter is dissolved and distributed as dilute sewage, is favourable to the development of disease germs, and experiment has shown how that the bacillus of typhoid fever is propagated throughout the soil, and it is very difficult to deny the importance of the soil as a possible breeding place for the germs of typhoid fever. In places where the soil is dry for part of the year, and dust storms occur in hot, dry weather, it is not very difficult to understand how columns of dust whirling across the country, loaded with faecal *debris* and pathogenic organisms, become a fertile source of spreading disease, more especially since the typhoid bacillus has considerable vitality. Diphtheria showing a tendency to recur year after year in the same district points to some connection between this disease and the soil, but all the evidence tends to show that the geological features of the affected districts play a less important part in the incidence of the disease than does soil dampness.

Diarrhœa is associated, according to Ballard, with the life-processes of certain micro-organisms in the soil, and it has a close relation with the earth temperature

at a depth of four feet. Cholera is often due to an imported contagion, but it may be due to certain local conditions, which may be either general sanitary defects or peculiarities of climate or soil. Cholera spreads most rapidly when the earth temperature is high and the level of the ground water is low. The bacillus of Anthrax will remain dormant in the soil for a considerable time, and the disease is especially prevalent in certain countries among animals grazing upon damp soils. The infection is usually derived through the discharges of a diseased animal or a dead carcass. Dysentery prevails in its worst form in a markedly damp and porous soil, with heavy rainfall and great nearness of the level of the subsoil water to the surface of the soil. Malaria appears to arise from the poison of decaying moist vegetable matter in marshes and forests. There is a specific microbe of malaria which thrives in a soil provided with moisture, air, a certain degree of warmth, and decomposing vegetable matter. It often follows on the disturbance of a dry soil. A malarious soil depends not on the nature of its inorganic constituents, but upon the presence of those conditions which favour the life of the specific organisms and bring about their aerial diffusion. There is some relation between dampness of the soil and the occurrence of Phthisis. Bowditch, of Boston, U.S.A., found that "The towns, villages, hamlets and houses which were situated at or near undrained localities, or were on heavy impermeable soils, or on low-lying ground, and whose sites were in consequence kept damp, had a very much larger number and proportion of cases of consumption than towns, villages, hamlets, or houses which were situated on dry or rocky ground, or on light porous soils, where the redundant moisture easily escaped."

Buchanan considers that the Phthisis Mortality bears a direct relation to the height of the subsoil water, and that when this subsoil water is lowered, and the ground dried, the recorded mortality of

phthisis falls. Here in the Metropolis of Sydney the greatest incidence of this disease occurs on the clay shale soils, and the effect of the sewerage system has been most marked. It is decidedly preferable that the ground water should be at a greater distance from the surface than it happens in some localities. In Alexandria, a suburb of Sydney (New South Wales), the ground water was formerly within a foot of the surface of the soil, but since the sewerage system has been installed, the level of the ground water is about 10ft. from the surface, with the result that this suburb, which was formerly most unhealthy, is now a fairly healthy suburb. Whilst speaking of the results of the contamination of the soil, it is as well to emphasize what we have before mentioned, viz., that the inherent warmth of a house is able to extract the ground air from the soil, and so there is a chance of contamination through this property of buildings. Porous sandy soils, such as exist in our eastern suburbs, are healthy, but on account of their very porosity they are liable to organic pollution, and when contaminated are likely to give off infective organisms on account of the free movement of the ground air. The dangers of a gravel soil have been pointed out by Sir Charles Cameron, who is of opinion that typhoid fever occurs frequently on such soils. Cultivated soils are not always beneficial in their action on account of the artificial manures used. Clay, although a cold soil, affords, especially when in slope, a far more healthy site than contaminated gravels or sand. Granitic and other impermeable formations, are termed healthy because the impurities, instead of passing into the soil, are carried off rapidly by the rainfall. These soils, however, may become unhealthy.

PARKES' TABLE OF SOILS IN ORDER OF HEALTHINESS.

—	Slope.	Permeability to Water.	Emanations to Air.	Substances into Water.
Primitive Rock ..	Great	Slight	None	Few
Clay Slate ..	"	"	"	"
Millstone Soil ..	Moderate	"	"	"
Gravels and Loose sands without Impermeable Subsoils ..	Slight	Great	Slight	Variable
Chalk ..	Moderate	"	Slight	Lime Salts
Sandstones ..	"	Variable	"	Variable
Sands within Per- meable Subsoils	Slight	Arrested by subsoil	Considerable	"
Clays ..	"	Slight	"	Alkaline mat- ter
Marshes ..	"	"	"	Often great
Limestones ..	Considerable	Moderate	Slight	Considerable
Magnesia ..	"	—	—	—

Geological formation, therefore, has an effect on the healthiness of the soil. Our eastern suburbs have a soil composed of sand upon a bedrock of rock, which has so good a slope that the sand is very rarely wet. In Erskineville the soil is composed of wet clay, and as the subsoil water is close to the surface, there is great difficulty in keeping the borough healthy. In Sydney, N.S.W., typhoid fever flourishes most upon clays, especially wet clays with an under stratum of shale. Sir Joseph Fayrer remarks:—"It is not enough that we know the seed, but it is necessary that we should also know the nature of the soil, the meteorological and other conditions which determine whether it is to grow and multiply or to remain inert or harmless. If one can learn how to destroy the seed, to sterilize the soil in which it attains its full development, or if we can neutralize the favoring conditions, and so prevent or impede its growth, then we shall have solved a great problem, and conferred a lasting benefit on mankind."

CHAPTER III.—FOOD.

The object of food is to repair the waste and administer to the growth of the bodily organs: to maintain a nutritive equilibrium between the bodily income and expenditure under all the varying conditions and circumstances to which the human organism may be exposed; to maintain all the functions of the body in healthy activity, and to prevent any loss of the normal body weight. A perfect food is, according to Dr. Burney Yeo, "that which comprises all the elements of which the tissues of any living thing, and all the solids and liquids of its body are composed." All living things undergo change, either in increase or decrease of bulk, and in the composition of the various tissues. Such change is a necessary and constant condition of life, and food is needed either for the growth and development of the young animal, or to maintain the integrity of the body structures, and to repair such waste as is involved in the exercise of their functions. In supplying a food it is necessary to supply such a one as will contain all the elements necessary for the maintenance of those chemical changes which are essential to the development of animal activities. "Every structure in the body in which any form of energy is maintained is nitrogenous. The nerves, the muscles, etc., are all nitrogenous. Even the non-cellular liquids passing out into the alimentary canal at various points, which have so great an action in preparing the food in different ways, are not only nitrogenous, but the constancy of this implies the necessity of the nitrogen in order that these actions shall be performed; and the same constancy of the presence of nitrogen when function is performed, is apparently traceable through the whole world." (Parkes.) Animals in the process of nutrition, and in the development of their various forms of energy,

not only appropriate the products of vegetable life, but convert them into other compounds, and all living organisms not only appropriate these food-substances, but also incorporate them into the tissues of their bodies. Through process of assimilation the animal obtains its store of potential energy. There are twelve elements which enter into the Composition of the human body: Carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, chlorine, iodine, potassium, calcium, magnesium, and iron. These elementary constituents, combined more or less into highly-complex bodies, are the proximate principles of the human organism. There are four great divisions of alimentary principles. 1st, the nitrogenous or albuminates, formerly called proteids; *blood fibrin, muscle fibrin, muscle substance, albumen, gluten, casein, globulin*. The members of this class can replace one another in the maintenance of nutrition, and resemble each other, being composed in similar weight proportions of carbon, hydrogen, oxygen, nitrogen, and sulphur. The 2nd group—the fats or hydro-carbons—resemble one another in chemical composition, and are especially rich in carbon. The 3rd class, the starches and sugars, is termed carbo-hydrates, and the 4th class includes water and mineral substances. Foods are organic and inorganic, nitrogenous and non-nitrogenous. The albuminate class or nitrogen containing group, play a very important part in the nutrition of the human body, for the members contribute to the formation and repair of the tissues and fluids, especially of the nitrogenous tissues. They regulate the absorption and utilisation of oxygen, and they may also contribute to the formation of fat. Fat may be formed at the expense of the albuminates, and nitrogenous substance is the regulator of oxidation and the transformation of energy. Albumen, together with water and salts, is the only alimentary substance which is able alone to support the vital processes. In fattening pigs Lawes and Gilbert

found that two-thirds of the fat stored up must have originated from other sources than the fat taken in food. Gelatin cannot replace albumen in the repair and maintenance of the tissues, but by its administration very large quantities of albumen can be spared in the body, or devoted to increase of bulk. Fat is not so readily split up into simpler bodies as albumen, and, therefore, is not the same easily combustible substance within the organism as it is outside. Fats administer to force production, and undergo destruction and oxidation in the process, so that the amount of carbonic acid given off during exercise is much greater than during rest. An individual taking 1435 grammes of meat, containing 48.8 grammes nitrogen, loses by the kidneys 50.8 grammes nitrogen; whereas, one who takes meat and bread, containing 83.5 grammes of nitrogen, and adds to it 191 grammes of fat, only eliminates 19 grammes of nitrogen. Glycerine, although a fat, raises the amount of albuminous waste. Carbo-hydrates check albuminous wastes, and they are converted into glucose before they are absorbed. Lawes and Gilbert calculate that 40 per cent. of the fat of pigs is derived from carbo-hydrates. Of mineral salts calcium phosphate is the most important in the body, and common salt occurs in all the tissues and fluids. The entire withdrawal of common salt from food would be speedily fatal. The state of malnutrition, which in its highest degree we call scurvy, appears to follow on the absence of lactates, tartrates, citrates, and acetates; and as these exist in green vegetables, it is a well-known rule of dietetics to supply them with great care, although their nutritive power is small. Water is essentially requisite for the processes of digestion and absorption and a solvent of food substances. Insufficient supply of water leads to disturbances in the circulation, the distribution of heat, and causes retention of waste products in the body. The man who chooses a complex diet, and feeds on meat, will be more active and more able to exert sudden violent effort than the vegetarian whose food

has equal potential energy, but is evolved more slowly. If we lift a weight in our hands, muscular force is employed in the act, and the energy evolved in this or any other muscular action must have its origin and source in something, and, as a matter of fact, this source is in the material which has been supplied to the body in the form of food. If we regard, therefore, the food which we consume as a direct source of heat and mechanical energy displayed by the body, it is obvious that we can obtain by their measures a fair idea of the nutritive values of the various food-stuffs. The force exerted by respiration, circulation, etc., equals 260 foot tons. The external work which can be done by a man daily has been estimated at one-seventh of the work of a horse and the kinetic energy which is obtained by transformation from the potential energy manifests itself in the form of muscular work and the production of heat. The usual day's work done by an adult ranges from 300 to 450 foot tons. When ascending a height a man raises his whole weight through the height ascended, and at a rate of 3 miles an hour would ascend one-twentieth part of the distance he would cover on level ground. Therefore if W = weight of parcel carried, X = weight of man and D = distance travelled in feet, then $\frac{(W + X) D}{20 \times 2240}$ foot tons = amount of energy.

Units of work can be converted in foot pounds by multiplying them by .007233, and into foot tons by dividing them by 311,000. As the heat production is related to the amount of chemical action ensuing, so likewise is mechanical power production, and we find that as a measure of the utility of food, the value of the various food principles as mechanical producers will correspond to their value as heat producers. As a store of energy in our bodies, the carbo-hydrates are, in a quantitative respect, about equivalent to the proteids. The heat equivalent of fats, on the other hand, is twice as great: One part of carbo-hydrates has the value of

one nutrient unit, one part of fat has the value of three nutrient units, and one part of albuminate has the value of five nutrient units. If, then, bread is a penny per pound, we get rather more than eleven nutrient units for one shilling. The average output for a man weighing eleven stone is 230 grammes of carbon and fifteen of nitrogen, and he requires at least 307 grains of nitrogen. If, then, such a man lived on bread, which contains 116 grains carbon and 5.5 grains nitrogen per ounce, alone, he would, to obtain the 307 grains of nitrogen needed, require to consume 3.1 lbs of bread, while, if he lived on meat, he would have to eat 4.7 lbs. Consequently, by choosing a mixed diet, he is able to obtain the requisite quantity of nitrogen from a smaller quantity of food. If a diet is supposed to yield five ounces of albuminates, three ounces of fat, fifteen ounces of carbo-hydrates, and one ounce of salt: then how much bread, salt butter, and Dutch cheese would be needed to supply a proper quantity of these principles?

The percentage composition of—

	Proteid.	Fat.	Carbo-hydrate.	Salt.
Bread	8	1	50	1.5
Salt Butter	—	80	—	3.0
Dutch Cheese	28	23	1	7.0

Calling bread a , butter b , cheese c :

$$\frac{8a + 28c}{100} = 5 \text{ proteid.}$$

$$\frac{1a + 80b + 23c}{100} = 3 \text{ fat,}$$

$$\frac{50a + 1c}{100} = 15 \text{ carbo-hydrates.}$$

Simplifying these equations, we have

$$8 a + 28 c = 500.$$

$$1 a + 80 b + 23 c = 300.$$

$$50 a + 1 c = 1500.$$

$$\therefore 50 a + 1 c = 1500 \times 28 = 1400 c + 28 c = 42000$$

$$8 a + 28 c = 500 \quad = 8 a \quad + 28 c = 500$$

$$1392 a = 41500$$

$$a = 29.8 \text{ ounces.}$$

If $a = 29.8$ ounces, then $50 a + 1 c = 1500$ becomes
 $1 c = 1500 - 1490 = 10$ ounces.

If $a = 29.8$, and $c = 10$, then $1 a + 80 b + 23 c =$
 300 becomes $80 b = 200 - 298 - 230 = 40.2$.
 $b = 0.5$ ounces.

Consequently it would require a meal of 30 ounces of bread, 0.5 ounces of butter, and 10 ounces of cheese to give the required quantity of the proximate principles. Animal food is digested more rapidly than vegetable food, and meat can replace the waste of nitrogenous tissues more rapidly than meal of any kind. The analysis of pure muscle shows it to consist on average of 76 per cent. of water and 24 per cent. of solids. Meat varies according to age, sex, state of nutrition, and part of the body. The flesh of young animals is less digestible than that of more mature ones, and there is less flavour, less stimulating properties, less nutritive value in the tissues of young animals. A four-year-old ox yields the best beef, and a three-year-old sheep the best mutton. The flesh of the female has a finer grain than that of the male. Beef is the most nutritious of all animal foods: its fat consists of glycerides of the fatty acids. Veal is less nutritious than beef or mutton. Mutton is more easily digestible than beef, as its fibre is shorter, but its fat is harder. Pork is the most difficult meat to digest on account of its fat, but when cured as bacon it is less likely to disagree

with the stomach. Poultry differs from ruminating animals in that its muscular fibres are not permeated by fat, and it is the relative proportion of fat which fish contains which determine their delicacy of flavor and facility of being digested, those which contain the least fat being more easily digested and of more delicate flavors. Many of the crustacea are nutritious, but they are indigestible, and may give rise to toxic symptoms. Oysters chiefly consist of liver, and are very digestible. Civilised man invariably cooks some portions of his food, and the cooking improves and develops agreeable flavors, and renders the food more attractive and agreeable to the palate. Cooking also enables food to be more readily masticated, and more easily digested, for the whole mass is rendered much less coherent and more susceptible of mechanical sub-division. Further, the exposure of food to high temperature affords a safeguard of destroying parasitic or other minute living creatures or germs, which may accidentally be present in the meat. Boiling is the simplest and most convenient way of cooking animal food. When meat is plunged into water, part of its soluble constituents pass out into the water, and if boiling is prolonged, more or less of the connective tissue is converted into gelatin and dissolved in the water. Boiling coagulates the albumen, loosens the muscular fibres and abstracts some of the soluble extractives, so that a joint in boiling loses 20 to 40 per cent. of its weight. By roasting, the nutritive juices and extractives are more completely retained in the meat, for the surface layers are coagulated and form a crust, which presents a barrier to the subsequent escape of the juices of the meat. Stewing is an economical method of cooking meat, as the loss is only about 20 per cent., and is chiefly due to the evaporation of water. In grilling, the meat is more scorched, but frying does not improve the digestibility of the meat. Animals should be inspected from ten to twelve hours before being killed; they should be well grown, well fed,

and of a fair age. An ox should weigh from 600 lbs., and its weight is determined by measuring the trunk from just in front of the shoulder-blade to the root of the tail, and taking the girth of the animal just behind the shoulder-blades. Multiply the square of the girth by 0.08 and the product by the length to obtain the dimensions in cubic feet, allowing 42 lbs. for each cubic foot, then: $(C^2 \times 0.08) L \times 42$, or $\frac{2}{3}$ $(C^2 \times 5 L) =$ weight in pounds. Sixty per cent. of the weight of an ox is meat, the skin is $\frac{1}{18}$ of the weight and the tallow $\frac{1}{12}$. A full-grown sheep will weigh from 60 to 90 lbs., and full-grown pig from 100 to 180 lbs. The age of an ox should be from 3 to 8 years. The age is told chiefly by the teeth, and sheep fit for slaughter should always have a clean, even set of teeth.

DENTITION.

OX—

Temporary teeth—

Part through at birth.

All incisors through in 20 days

First, second, and third pair of molars in 30 days.

Teeth large enough to touch each other in the sixth month.

SHEEP—

Begin to appear first week.

Fill the mouth at 3 months.

Fall 15 to 18 months.

PIG—

Complete in 3 or 4 months.

Permanent teeth—

		OX.	SHEEP.
1 year	...	0	2
2 years	...	2	4
3 years	...	3	6
4 years	...	6	8
5 years	...	8	—

At six years in an ox the border of the incisors has been worn away a little below the level of the grinders. At seven years the first grinders are beginning to wear, and are on a level with the incisors. At eight years the wear of the first grinders is very apparent. At ten or eleven years the used surfaces of the teeth begin to bear a square mark, surrounded with a white line, and this is pronounced on all teeth by the twelfth year. In sheep the wear of the teeth begins to be marked at about six years. The age of the pig cannot be told with certainty by the teeth after the age of three years. The condition of cattle is told by the firmness and compactness of the flesh. The twist or parta between the two buttocks should stand prominently out, the flank should be full to the hand, and drop into it as the animal is handled; the rib should be well covered with compact flesh, and the cod or udder should be a large lump of firm fat. A quick bright eye, moist red nasal mucous membrane, easy regular breathing, no odour to the breath, quiet circulation, and natural appearance in excreta shew a healthy beast: while a rough coat, dry or foamy nostrils, heavy eye, protruded tongue, difficult breathing, slow movements, diarrhœa, hot teats, scanty or bloody urine denote a sick animal.

Pleuro-pneumonia begins gradually, but the temperature soon rises to 104deg. to 105deg.; the animal refuses food, breathing becomes laboured and painful, short, dry cough is present.

Foot and mouth disease.—Is recognised by an examination of the mouth, feet, and teats, which are covered with white fluffy patches.

Plague.—Animal soon becomes weak, with hanging head, drooping ears, shivering, running from eyes and mouth, peculiar state of tongue and lips, stopping of chewing of the cud, abdominal pains, excessive diarrhœa.

Anthrax is a general or local affection, with fever. Boils and carbuncles appear with erysipelas, and the bacillus anthrax may be detected in the blood.

Tuberculosis, or grapes, is sometimes acute, but more often chronic. At first there is dulness, increased sensibility, especially of the back muscles or chest walls; later, emaciation comes on, with loss of appetite, shortness of breath, and cough.

Actinomycosis, caused by "ray fungus," attacks the lower jaw, and tongue, also the lungs and bones, and leads to general malnutrition, and is sometimes fatal. Sheep also suffer from splenic apoplexy or *braxy*. The animals have peculiar look, staggering gait, bloodshot eyes, rapid breathing, full and frequent pulse, scanty secretions, a great heat of body.

Fluke disease or *rot* causes dulness, sluggishness, rapid-wasting, diarrhoea, yellowness of eye, and falling of the hair.

Measles in the pig is caused by *cysticercus cellulosæ*, which makes its home in the tissues of the animal, and causes a bloated appearance of the body of the animal.

Trichina spiralis is found in the muscle and fat of pigs in large numbers.

Meat should be inspected directly the animal is killed. The quantity of bone should be 17 to 20 per cent. of the meat, so that in lean animals there would be a greater proportion. In a fat ox the amount of fat is one-third of flesh; in a fattened pig, one-half. In beef we find the surplus fat in excessive quantity at the kidneys – pelvic cavity, cod fat, and udder. In mutton it is that fat which is on the back and in the region of the kidneys. The colour of the fat should be white or straw colour, but in the horse it is yellow, with an unpleasant taste. The muscles should be firm and yet elastic, not tough; pale, moist muscle denotes a young animal, and dark coloured an old one. A deep purple tint shews that the animal has not been

slaughtered Good meat should exude a reddish juice, have sweet odour, pleasant flavour, marbled appearance from ramifications of little veins of fat among the muscles. There should be no lividity, no soft gummy fluid or pus, and the inter muscular tissue should not tear easily as in commencing putrefaction, which, when it sets in, causes the meat to become paler, of weak consistence, with an unpleasant odour. Plunge a knife into the flesh right up to the hilt. In good meat the resistance is uniform, and there is no smell on the blade of the knife when it is withdrawn. In young animals up to six years of age the bones are joined by gristle. A horse has eighteen pair of ribs, while an ox has only thirteen pairs. The tongue of a horse is smooth, and the colour of the flesh is much darker.

Sausages should only give off a faint smell when mixed with boiling water and limewater, but bad sausages give off a very strong ammonia-like smell.

Refrigerated Meat.—Shanks are bruised by chain, fat is pink, outside of meat is a dead colour, pizzle and root are always entirely removed. *Cysticercus cellulosae* can generally be detected as round bodies, giving the meat a flabby appearance. *Trichinosis* is detected by the presence of small round tough specks in the meat, and with a microscope, these bodies are readily made out. The flesh of apparently healthy animals may produce poisonous symptoms, as for instance, pork may be affected by the unwholesome garbage upon which the pig feeds. The flesh of healthy animals, when decomposing, is eaten sometimes without danger, but it may give rise to vomiting, diarrhæa, etc., and cooking does not appear to entirely check the decomposition. Hence sausages, pork pies, and even beef steak pies sometimes become poisonous from the formation of ptomaine. If meat is kept in dark, damp, unventilated places, to which sewer gases can gain access, the

probability of the development of poisonous properties in the meat is largely increased. In Edinburgh some years ago, a bride and several members of the bridal party, after partaking of breakfast, sickened and died. Careful investigation showed that all those affected had partaken of a particular ham. Now, this ham had been dressed in an ornate fashion with gelatine, and before being placed on the table had been kept all night in a cellar. The gelatine was found to be teeming with colonies of pathogenic germs. Animals killed by accident are not desirable for food, as the flesh is usually dark and discoloured from not having been bled, and is also in a state of incipient decomposition. Diseased animals should never be used for food, but should be destroyed. From the appearance presented by tubercular deposits in the serous linings of the chest and belly, animals suffering from well-marked tuberculosis are said to have the grapes. *Fish* contains a large quantity of phosphorus, which makes it a very suitable diet for people of sedentary habits, because it is easily digestible. Fish should be eaten fresh, and should be firm, stiff, with bright eyes and red gills. With strong pressure of the thumb and finger the flesh should not crush or they are unsound. Fish, even when apparently healthy, may produce poisonous symptoms, and one form of tapeworm is known to be communicated by certain fish. In *milk* are found the four classes of alimentary principles, for it is a perfect and complete food which sustains all young mammalian life, and is rich in nitrogen, fat, sugar and water. Casein is one of the principal nitrogenous foods which, when coagulated forms cheese. The fat of milk, which is really a collection of small oil globules can be separated as butter, and one part of cream = 0.2 of fat. Pure milk should yield at least 8 per cent. of cream. The carbohydrate of milk is milk sugar. Milk when drawn from the cow should be perfectly fluid, slightly frothy on the surface, opaque and white, with a faintish buff tint.

It should have an agreeable peculiar odour and a pleasant sweet taste. The specific gravity of milk as found by the lactometer varies between 1026 and 1034; but the addition of water lowers the specific gravity, as does also an excess of cream. The sugar of milk undergoes fermentation under the influence of *Bacterium lactis*, but there are other micro organisms which can produce coagulation of milk, and turn it sour. By boiling milk this fermentation is checked, and the micro-organisms are destroyed. The nature of and quality of the food supplied exercise a considerable influence over the amount and quality of the milk. The first drawn milk or fore milk is poor in fat, while the strippings or last portions are rich in fat. Milk is one of the most easily contaminated of all foods, and as it is always used freely as a food it very freely communicates disease. Cows affected with disease not only may communicate such diseases to the milk before it is drawn, but may even infect it afterwards. Milk may be preserved by condensing it in vacuo and adding cane sugar, but such milks are generally low in the percentage of fat. It can also be preserved by heating it up to 250° Fahrenheit, and keeping in a hermetically sealed bottle, or by the addition of boracic acid, salicylic acid, or formalin. The chief adulterations of milk are: The addition of water; removal of part of cream and addition of water; the addition of starch, flour, gum, etc.; the addition of preservatives. Placed in a tall glass, milk should be opaque, white, have no deposit, no smell or taste; should not change in appearance when boiled. It should have a slightly acid reaction, but should not be pronounced acid or alkaline. When milk is allowed to stand, the globules of fat rise to the surface and form the cream which is of lower specific gravity than the fluid portion. Cream is estimated by filling a long glass tube, graduated to 100 parts, with milk, and allowing it to stand for 24 hours.

The cream rises to the top, and the thickness of the layer is read off. About 8 per cent. is the average amount of cream in milk, but if it falls below 5 per cent., it is probable that the milk has been adulterated with water. The specific gravity of milk varies between 1.026 and 1.034, being less as the proportion of fat is greater. Three degrees of specific gravity are lost for every 10 per cent. of water added. By Vogel's lactoscope the fat in milk can be determined. Milk from a healthy cow is free from microbes, but these may find their way into the milk from the udder, the hands of the milker, particles of dung, dirty cans, and the air of the cowsheds. If the milk is deprived of a large part of its lightest constituent, fat, it becomes specifically heavier, but by the addition of water the specific gravity can be brought back to its true height. This renders it difficult to detect the acts of the milk sophisticator. Watering alone lowers the specific gravity and diminishes the amount of cream, while creaming or abstracting a portion of the cream from the milk raises the specific gravity and diminishes the quantity of cream. The fixing of a standard of milk usually detects the fact that both watering and creaming have been perpetrated on the same sample. Starch, which is added to conceal the thinness of milk, can be detected by the blue colour it yields with iodine. Chalk, which gives colour, effervesces with acid. Cream may be adulterated with magnesia and arrowroot. Boracic acid may be detected by the green colour it imparts to the flame of a Bunsen burner. Salicylic acid gives a deep purple colour with ferric chloride. Butter is the fat of milk clotted together; it should contain 8 to 12 per cent. of water, 3 per cent. curd, and 84 to 93 per cent. of fat. Sometimes it contains more water, as this has been added to make the butter heavier in weight. Margarine is merely animal fat, sometimes mixed with milk. The specific gravity of butter fat is 0.911 to 0.913. An adulterated butter may have sp. g. .902 to .904, and an artificial

one 0.859 to 0.861. Cheese is coagulated casein. Its quality is known by taste, and its chief adulteration is starch. As cheese ripens it forms more salt. Bread-making is one of the most important cooking processes, and by it flour is converted into a firm and porous substance, which can readily be masticated, and which, while it retains a certain amount of water, is not noticeably moist or sticky. In making bread, the yeast fungus, *Torula cerevisiae* is the active agent which converts the sugar in the dough into alcohol and carbonic acid, so that the mass gradually swells up and the sponge rises. Under the influence of the heat of the oven an expansion of the entangled vesicles of gas ensues, and occasions a further rising of the dough; and with the subsequent setting of the substance of the loaf, a permanently vesiculated mass is formed. The effects of the heat on the constituents of the flour is to increase their digestibility, to change the nitrogenous constituents, to rupture the starch granules, and to convert a portion of the starch into dextrin and grape sugar. Bread contains a large amount of carbo-hydrates, and with the addition of some nitrogen is a perfect food. Bread may be of bad colour from old flour or bad yeast, or the admixture of meal other than flour. It is frequently heavy through bad yeast fermenting too rapidly, or when the fermentation has not taken place. It becomes rapidly mouldy with an excess of water, and is made heavier by the addition of rice and potatoes. Alum is added to check the excess of fermentation, and if in too large a quantity would cause constipation. Excess of alum may be detected by thrusting a steel knife into a hot loaf, when the alum will show as white spots on the blade. Food may be preserved by drying by exclusion of the atmospheric air, or what is the same thing, by covering the food with an impermeable coating, by exposure to cold, by treatment with preservative agents. Extracts of meat are

prepared by exposing the meat entirely free from sinew to a moderate heat for some hours.

Prepared Concentrated and Preserved Foods should be nutritious, portable, easily cooked, and not liable to deterioration. The methods used to preserve foods are :—1. Freezing or refrigerating. 2. Salting and the use of various chemical agents. 3. Drying. 4. Exclusion of air and hermetically sealing in tin cases. As in salting, meat loses much of its nutritive qualities, the use of salted meat to any extent is not to be recommended. Besides salt all kinds of chemical agents have been tried as food preservers.

Boracic Acid has no odour and is supposed to prevent putrefaction of animal and vegetable substances, but its antiseptic powers are very low. *Glycerine* is not hurtful, it is sweet and it does not ferment, but in order that it may exercise its antiseptic powers it has to be used in such quantity that it confers a penetrating and unpleasant sweetness.

Salicylic Acid.—Its action on ferments and microbes is often only temporary, and experience has shown that poor wines to which this acid has been added (1·5 grammes per litre) soon undergo fresh fermentation of acid or putrid character. It is a most objectionable preservative, especially in milk which is destined for young children. In Sydney, N.S.W., wine adulterated with salicylic acid has been condemned.

Bisulphites act by absorbing oxygen, and by suspending the growth of moulds and ferments. They are objectionable for use in canned goods because they dissolve the tin and lead from the metallic envelope.

Carbonic Acid has a special antiseptic and even disinfectant action, and is chiefly used in sparkling waters and wines.

Creosote has been used for preserving putrescible organic liquids and for keeping meat, but it is dangerous and unpleasant, as it suspends digestion.

Acetic Acid can inhibit the growth of all bacteria, provided the vinegar used is strong, but if it be weak it may itself undergo putrefactive change.

Formaldehyde is among the first three or four antiseptics in value, and even when of too weak a strength to prevent growth, it postpones development.

In the absence of microbes change in food by oxidation is comparatively slow and rare. Simple oxidation never renders substances injurious. Certain canned foods have a peculiar taste which is due to some action on the fluids by the metal, but although this is unpleasant it is not necessarily injurious. Vegetable substances may be blackened through some action of the metal covering. Lead may be present in tinned goods and is derived from the solder, and Helmer has stated that all canned goods contain tin in solution. Rubber bands which are coloured with red lead may contaminate preserved goods. If the inside of the tin be much discoloured, or if tinned fruits show a strongly marked crystalline appearance on the interior surface they are unsafe as food. Any discoloration of the contents, or any peculiar odour or taste, should be regarded with suspicion.

Yeast Moulds and *Bacteria* of all kinds can be carried in the dust of the air on to the surface of any exposed food and set up fermentative and putrefactive changes. If it were possible to exclude air and dust, changeable bodies could be preserved, but the air contained in such bodies and the few germs which it is impossible to keep out, are sufficient to bring about their decomposition. Care should be taken that all tins of preserved foods keep their shape; tins which have lost their shape are to be regarded with suspicion.

Drying.—Dessication leaves the fibre and dried juices of the fruit incapable of putrefaction, but the flavour and digestibility are much impaired.

Smoking is accomplished by allowing the surface of food to become dried and impregnated with the

by balancing

smoke of peat or wood. Smoking has only a surface preservative action, and does not reach the interior, so that the ova of trichina, tapeworm, etc., remain undestroyed. Kipperd herrings are often prepared under most insanitary conditions, and as the treatment is often far from complete, may be a source of danger. It is to be remembered that most micro-organisms are not killed by cold. Considering the minute quantity of formaldehyde needed for preserving food, and the fact that it does not in any way change the freshness or appearance, there cannot be any objection to its use.

Condensed Milk is prepared by sweetening the milk with sugar, and evaporating it slowly in vacuo at a low heat for two or three hours. The tins are sterilised by scrubbing, steam, and pure cold water.

Bread acquires from the air germs of all kinds and may become poisonous, and bakeries should be under constant supervision as to ventilation and cleanliness, for it is useless to combat bacteria when they are allowed to multiply in the daily food.

The sanitary inspector may be called upon to give his opinion as to the soundness of certain cheap wines. These are often adulterated by adding water, distilled spirits, artificial colouring matters, lime salts, tannin, alum, lead, copper, etc. Water, if added, is not deleterious, though it interferes with the taste and strength of the wine, and diminishes the amount of alcohol. Inferior distilled spirits may be added which alter the flavour and digestibility of the wines. Certain artificial colouring matters are used to give character to the wine; these are not always harmful, but serve to hide injurious adulteration by spirit, etc.

Tea may be adulterated with willow leaves, and exhausted tea leaves, and sometimes clay and lime are to be found.

Coffee is at times adulterated with chicory, dates, beans, maize, and acorns. Chicory is a legal addition and is itself sometimes adulterated with powdered liver, carrots, etc.

CHAPTER IV.

WATER.

Water is an essential of human existence. It forms 58·5 per cent. of the body weight, 70 per cent. of the blood corpuscles, and 90 per cent. of the serum of the blood. The composition of water is by volume two parts of hydrogen and one part of oxygen, and by weight one part hydrogen and eight of oxygen. Water attains its maximum density at 4° C.* at the ordinary atmospheric pressure at the sea level. It boils at 212° F. or 100° C., and evaporates at all temperatures. Water is only compressible to a very slight extent. Under an additional atmosphere of pressure 1000 volumes of water become 999·95 volumes. Changes in the biological and chemical condition of water are constantly taking place, and a water which is not chemically and bacterially pure may still be quite safe for dietetic purposes. It is estimated that from 10 to 15 gallons of water per day per head are required for personal and domestic use, 5 to 10 gallons for municipal purposes, and a similar quantity for trade purposes; but this quantity varies greatly in different countries and with different classes of houses. Parkes allows 6 gallons per head for domestic washing, 5 for ablutions, 6 for water-closets, 4 for general baths, and 3 for unavoidable waste. The Metropolitan Board of Water Supply and Sewerage of Sydney, N.S.W., supplies about 44 gallons per head per day. After air, water is the first requirement of life, and impure water is as fertile a source of disease as is impure air. Water is never found chemically pure in nature. It is always mixed with various gases, and organic and inorganic impurities. Rain is probably free from bacteria and organic

* 39·2° Fahrenheit.

matter as it falls from the clouds, but in falling, any material suspended in the atmosphere will be absorbed or dissolved, and carried down to the earth into the usual receptacles and channels for the discharge of rainfall. Bacteria and matter from soil is washed into the streams and contaminate the supply. There are few solids or gases which water does not dissolve to some extent, and its solvent powers are generally increased by a rise of temperature in the case of solids, but decreased in the case of gases by either a rise of temperature or a diminution of pressure. Water absorbs gases, such as ammonia and hydrochloric acid, in large quantities, and it also dissolves the gases of the air, oxygen, nitrogen, and carbonic acid in small quantities. Rain water collected from a rocky surface, sparsely occupied by population, and deep well waters or water derived from deep-seated springs, are the purest attainable water supplies. As water is an essential to existence, it is very necessary that such an essential shall be as pure as possible. The prime source of water supply is rain, which when it leaves the clouds is, as before stated, quite pure, but absorbs or intercepts any suspended matter which may be existent in the atmosphere. These impurities are most evident in the neighbourhood of towns, on account of the organic and inorganic dust of habitations and the tarry, carbonaceous matter in the smoky atmosphere. During the early part of a shower, ammonia is found in largest proportion, and one litre of rain, about a quarter of a gallon, contains 25 cc.† of gases, or about ·8600 fluid ounces, viz., oxygen 8 cc., nitrogen 16 cc., carbonic acid 0·5 cc. Waters generally made use of for drinking purposes are classified as—

Safe Waters —

1. Spring water.
2. Deep well water.
3. Mountain, river, and lake water.

† cc. Means cubic centimeters, and there are 1000 ccs. in one litre.

Suspicious—

4. Stored rain water.
5. Surface water from cultivated land.

Dangerous—

6. Polluted river water.
7. Shallow well water.

Spring water is justly looked upon as the best kind of water for all ordinary purposes. Springs are merely underground reservoirs of water at a greater height, or they may be the outflow of lakes or other elevated sheets of water from deep sources. Spring water is usually free from dangerous impurities, as the source from which it comes is generally protected; or, if not, the passage through the earth filters it to a great extent. Among the purest water supplies of the world are those of Munich, Vienna, and Copenhagen. These cities all obtain their water supplies from springs in the Mangfatt Valley of the Bavarian Alps. The water supply of Vienna comes from Schneeberg, in the Austrian Alps. Deep wells, from 60ft. downwards, are generally good sources of supply; at least, if they penetrate through one or more impermeable strata, such as rock or deep clay. Artesian wells are artificial springs, made by boring deep into the ground until a layer of water is struck, which at some part has a higher level. From the great depth of such wells the water is generally free from any dangerous impurity. The nature and amount of the mineral contents of water obtained from springs or deep wells are determined by the soluble constituents of the various strata through which the water has passed, and the organic impurities are regulated by the facilities for pollution of the superficial soil and the completeness of purification lower down.

It will be convenient at this point to define what is meant by deep wells, as opposed to surface wells, and also the difference between true, or deep-seated springs, as opposed to the mere outflow of surface

waters, which may have all the appearance of a true spring water, while in reality they are merely the outflow of surface soakage waters.

The term deep well water is used to denote a water derived from a water-bearing stratum, protected from surface soakage by an impervious layer or stratum, as clay, shale, or the like. A shallow well is one sunk to an underground water level which is not so protected. It will thus be seen that the terms deep and shallow wells refer to conditions which are often independent of mere depth below the surface, and it may often happen that a water obtained at a comparatively short distance from the surface is yet of the deep well class, while one derived from a much greater depth may yet be only a shallow well water. Similarly a spring, so-called, may merely be the outflow of soakage water on a hillside above the outcrop of an impervious stratum, and corresponding in reality to a shallow well water, while a true spring is one finding its way to the surface from a deep-seated, water-bearing stratum through fissures in an over-lying and impervious, and, therefore, protective, over-stratum. These differences are most important, and careful examination is necessary in these cases in order to determine the true character of any such source of supply.

The sources of water supply for cities, are rivers, natural lakes, large impounding reservoirs, etc., situated, if possible, at elevations sufficient to furnish a supply by gravitation. Rivers are by far the largest source of water supply, and it is, therefore, necessary to see that the drainage area of such rivers is kept free from all chance of contamination; for, although dilution reduces the chances of single individual imbibing a fatal germ in drinking the water, still the germ itself will be just as dangerous, and may be more dangerous when imbibed. To thoroughly protect any catchment area of any water supply, it is highly desirable that such an area should be laid waste, and be kept free from habitation

by men or domestic animals. Domestic animals are not always in a state of good health, and evidently any disease germs which may be in the excreta of these animals if scattered over a given watershed, will be washed into the streams, lakes, or reservoirs with each succeeding storm. The city of Manchester (England) recognised the importance of this so much that, in addition to buying Lake Thirlmere, much of the approximated rainage area was also acquired. The water supply of the city of Sydney is obtained from a large catchment area, much of which is uninhabited, sloping towards several small streams, which pass into two rivers—viz., the Cataract and the Cordeaux, from which the water is taken by covered and open channels to a large impounding reservoir at Prospect. Stored rainwater is always to be regarded with suspicion, owing to the great difficulties experienced in preventing impurities from getting into the tanks used for storage. Such tanks should be closely covered, well ventilated, and provided with an overflow, discharging into the open air, away from any source of effluvia. They should also be frequently inspected and cleansed.

Rain water is often stored in underground tanks, and these have several advantages, although there are disadvantages, and even it may be, danger attending their use. Their situation underground leads to the water remaining deliciously cool in summer owing to the influence of the earth temperatures, and in cold districts the same influence prevents the water freezing in winter time. The excess of carbonic acid in the ground air, if it obtains access to the tank, passes into solution in the water, and so greatly improves its palatableness. Natural rain water is very flat to the taste from the absence of dissolved gases. On the other hand, the situation of an underground tank usually renders an emptying and flushing pipe impossible, and hence, the increased

difficulty of cleaning out often leads to the neglect of this necessary precaution. It is, therefore, the more needful in the case of underground storage tanks to strain and filter the rain water before it enters the tank. Any simple form of strainer and filter bed of sand or pea gravel may be adopted for this purpose; but perhaps the safest and most reliable apparatus is that known as Roberts' Rain-water Separator. The diagram shows the principle of this apparatus, though the form has been varied in those made more recently, principally with a view to save loss of head, which is often an important point.

It will be observed that by an automatic action the pure water following the first washings from the roof or other gathering ground is directed into a separate channel. In this way the first of the shower carrying with it the dust and other deposits which have accumulated between showers, can be run to waste, or stored in a separate tank and used for purposes other than cooking or drinking, while the following *pure* water is automatically directed into the pure water tank. The apparatus is so constructed that on the cessation of the rain the director automatically returns to its first position, so that without any attention it can be depended upon again to direct the first washings from the next shower to the waste pipe or first washings tank. The only objection which can be urged to this excellent apparatus is, that in the event of a succession of light short showers all the water would run to waste or to the impure water tank, although after the first shower or two the subsequently gathered water would be perfectly pure. This is undoubtedly a serious objection where, as in many parts of Australia, rain water is a scarce and valuable commodity. To meet such cases there are, however, means provided whereby the separator can be fixed so as to deliver only into the clean water tank. Of course the separator should be usually left in its normal position. On the arrival of showery weather, and after the first

cleansing of the gathering surface, it is locked as above described, care being of course taken to unlock it on the departure of the wet weather. One of these machines may be seen at the Museum of the Department at the Sydney Technical College. The objection raised to land drainage water is that there may be possible danger in its composition. It is believed typhoid fever is more persistent in those districts where the water is abnormally high in nitrates and nitrites, and it is probable that subsoil drainage of farm lands is concerned in maintaining this conviction of nitrates and nitrites in adjoining sources of water supply. In times of heavy rain much impurity of animal and vegetable origin is washed from cultivated land into the watercourses, and an epidemic of typhoid fever in Nice was traced to such a source. Shallow wells are always a source of danger as they are very readily contaminated through organic matter being washed into them from the soil, and through the possibility of sewage soaking into them. Tracing of disease through sewage-polluted water may be obscure; but although it may be difficult to discover the actual germ from which the disturbance springs, it may be, and probably is, there all the same, for pure water cannot create a disturbance of the animal system or be the cause of ill-health. Certain inorganic impurities in what appears to be pure water may cause disease. Of course a water may become partially purified and lose some of its organic pollution through oxidation, by means of agitation and aeration, assisted by aquatic plants and microbes. Bacterial action splits up the organic matter into carbonic acid and other gases, and into nitrogenous compounds. All the common forms of bacteria found in water are saprophytes which live and propagate their kind only upon dead organic matter.

The smallest quantity of sewage, making no perceptible difference in the whole volume of water, will yet pollute it; and although such pollution cannot

be discerned by optical or chemical tests, it will always render such a stream a questionable source of water supply. In a source of water supply polluted by trade effluents, refuse of dye works, slaughter-houses, household refuse, and sewage purification by filtration, the organic matter is insignificant in its proportion to the whole bulk, but putrefaction goes on, and the suspended matters are slowly deposited in the bed of the stream. Seasons of drought also affect the water supply, and permit any pollution of the stream to remain in it more or less undiluted, owing to the diminution of water flow. All infectious diseases (putting aside the matter of personal contact and food) must be transmitted to human beings from the air, the soil, or the water. Water may be polluted, and when polluted generally shows some evidence of its pollution either to the naked eye, to the microscope, or by its action on human beings. The possibility of its pollution by domestic animals is assured, and this is made evident through the fact that *bacillus coli communis*, which has been found in polluted water when no other germ was present at the same time, is also found in the intestines of man and animals. Some diseases of cattle and sheep are recognised as diseases of man, and Professor Ray Lankester is of opinion that a *bacillus coli communis* excreted by an animal may, if it passes into the intestines of man, become there, the bacillus of typhoid fever. So called pathogenic germs have their virulence exalted by other so-called non-pathogenic germs, and it may be that the *bacillus of typhoid* is merely an exacerbated form of the *bacillus coli communis*, which is certainly an adjuvant factor of this fever. At any rate, no catchment area of water supply can ever be regarded as proof against all possible contamination so long as it is inhabited by domestic animals.

The geological formation of a district influences the composition of the water running through it, though it is impossible to tell with absolute certainty

what the constituents of the water may be. Water from springs in granite is very pure, bright, clear, and palatable. The total solid constituents in these waters vary from 1·4 to 9 parts 100,000. Shales, slate, and sandstones, as they contain a large amount of soluble matter, yield to water a large amount of solid material, which, however, is nearly all harmless; and, as the proportion of organic matter is small, the clear, sparkling water is well suited for drinking and cooking purposes. Water from gravel soils is generally impure, and the amount of solids varies from 30 to 170 parts per 100,000. All surface and subsoil water is to be regarded with suspicion, as they are often very impure through contamination by sewers and cesspools and surface washings. In towns and among the habitations of men, the surface water and shallow well water often contain large quantities of calcium and sodium nitrites, nitrates, sulphates, phosphates, and chlorides. The nitrates in this case probably arise from ammonia, ammonium nitrate being first formed, which dissolves large quantities of lime. If the amount of sodium chloride is large, it can be supposed that the water has been contaminated by sewage. Water from wells near the sea frequently contain so much saline matter as to taste quite brackish, although the organic matter may not be large. Water may be polluted at its source, in its course or at its periphery of supply. Open conduits are liable to be contaminated by surface washings carrying leaves, clay, sand, and animal matters from cultivated land, and to these must be added those sources of impurity arising from the refuse of houses, trades, and factories. The organic or nitrogenous matter undergoes a gradual change, with the formation of ammonia, nitrous and nitric acids. On keeping the water the nitrites disappear, and in some cases the nitrates also gradually diminish, both actions resulting from the action of bacteria. Many of the organic matters are

not in solution but in a state of fine suspension, and among this suspended organic matter many minute plants and animals are always included. During its passage in the open conduits purification goes on by means of subsidence, by the action of ordinary water bacteria on pathogenic micro-organisms, should these be present in the water, by exposure to direct sunlight, and by the presence of water plants. It is not every kind of organic matter in water that has a disastrous effect, and it is doubtful whether such substances really exist in solution or are only present as suspended matter or sediment. Vegetable matter is probably present in all waters of a natural kind, and when it is derived from marshes, is often distinctly hurtful, but when from such sources as peat, is quite harmless. Animal matter, however, is a true source of dangerous impurity, and is usually derived from the sewage of cesspools and leaking drains. Water may be turbid either through suspended mineral matter or through the presence of organic matter which may include many living organisms. Such living organisms as water fleas and worms, do not indicate through their presence that the water is unfit for drinking, for it has been found that they will not live in dangerously impure water. Still, it is better that drinking water should be quite free from all living organisms. Water should be clear and entirely free from sediment or suspended matter; it should be colourless, bright and sparkling, with a pleasant taste, and quite devoid of any smell. When water is stored in wells, tanks, or cisterns, there is a very great chance that substances, either of harmless or hurtful nature, will get into it. And it is astonishing in how many ways such contamination may occur, and how difficult it is to detect its occurrence. Surface washings, soakage, leakage from pipes, passage of foul air through pipes and direct absorption of air by an uncovered surface of water all tend to introduce impurities into wells, tanks, and cisterns. Impurities of water may arise while it is being distri-

buted, either through metal pipes being partially dissolved, through wooden pipes rotting, and, if the pipes are occasionally empty, through impure air being drawn into them and being absorbed by the water which afterwards passes through. In Melbourne the street hydrants were placed in the gutters, and were of that kind known as ball hydrants, in which the ball is kept in position by the pressure of the water from within. When the pressure in the pipes fell at any time, the ball fell also, with the result that the overlying muck of the sewers was washed into the water-pipe and contaminated the water. Consequently, the distribution of a water supply to be truly safe must be truly continuous, and the pipes must be placed in such relation to sources of impurity as to render the occurrence of pollution impossible, even through imprudence or ignorance. Insufficient supply of water, or difficulty in removing water already supplied, gives rise to very similar results, so that an adynamic state of health occurs, and diseases of an epiphytic and zymotic nature arise. Under ordinary circumstances the sensation of thirst never permits any great deficiency for a long time, and the water-removing organs eliminate with wonderful rapidity any excess which may be taken. Enforced thirst, however, lowers both the muscular strength and the mental vigour. When disease poison does get access to water it is apparently more than ordinarily violent, but Simon has pointed out that "we cannot expect to find the effect of impure water always sudden and violent; its results may be and are often gradual, and may elude ordinary observation, and yet they are not the less real and appreciable by a close inquiry." *Diarrhæa* is not only produced by a water which is impure through suspended and dissolved organic matter, but also by certain waters which contain suspended mineral matters, such as clay, mica, and *debris* of plants, and also dissolved salts of chlorine, magnesia, lime, &c. *Dysentery* is a

disease of impure water, polluted either by organic matter or having in solution certain mineral salts. *Typhoid fever* may be propagated by water as well as through other vehicles of infection; and epidemics of this disease have been positively traced to water which has been befouled by sewage. *Dyspepsia* may be produced by those hard waters which lessen the secretions, and cause visceral obstructions through constipation. *Malaria*, *goitre*, and those *parasitic* diseases which are caused by tape-worm, round worm, fluke, &c., have also been traced to impure water. *Metallic poisoning* may be caused through water holding in solution portions of the metal receptacles in which it is stored, or of the pipes through which it is distributed. Waters which act on lead are—(1) the purest and most highly oxygenated; (2) those containing organic matter, such as would be derived from sewage; (3) those containing chlorides; (4) those containing a free acid, such as peaty water. New lead pipes give up more lead than old ones, and hot-water pipes yield up more lead than cold-water pipes. Any quantity of lead over 1-20th of a grain per gallon (0·07 per 100,000) should be considered dangerous, but 1-100th of a grain has been known to produce lead paralysis. Lead pipes, therefore, are to be avoided in all instances, and where lead has to be used through compulsion, either for water-pipes or cisterns, some method should be adopted to prevent the water from being capable of acting on the metal, or some means adopted to prevent the water coming in contact with the lead. Good iron pipes are, however, taking all things into consideration, the safest. The Hunter River water supply has a curious action on the galvanized iron cisterns used for storing the water for water-closets. The action of the water corrodes the substance of the cistern. Lead is also strongly acted on by this water.

Examination of Water.—A stoppered glass Winchester quart holds $2\frac{1}{2}$ litres, or $\frac{1}{2}$ -gallon of water. To take a sample, first rinse the bottle out with a small

quantity of hydrochloric acid, and after that with some of the water of which a sample is to be taken, taking great care that all trace of the hydrochloric acid disappears. Empty the bottle well, and then fill it up to the neck with the water to be examined. To obtain a sample, in the case of rivers or ponds, plunge the bottle mouth down under the surface of the water to some distance below the surface, and well away from the margin, so as to exclude scum and *debris*, care being taken not to stir up any sediment. Tap water should be allowed to run for some time before sampling, otherwise it will contain impurities from the pipe and nose of the tap. No samples of water should be kept longer than a day or two before examining them.

The fullest information ought always to be furnished with the sample as to—

- (a) *Source of the water*, viz, tanks, cisterns, main, house pipe, spring, river, stream, lake, or well.
- (b) *Position of source*, strata, so far as known.
- (c) If a *well*, depth, diameter, strata through which sunk, whether imperviously stined in the upper part, and how far down. Total depth of well and depth of water both to be given. If the well be open, furnished with a cover, or with a pump attached.
- (d) *Possibilities of impurities reaching the water*: Distance of well from cesspools, drains, middens, manure heaps, stables, etc.; if drains from sewers discharge into streams or lakes; proximity of cultivated land.
- (e) *If a surface water or rainwater*: Nature of collecting surface and conditions of storage.
- (f) *Meteorological conditions*, with reference to recent droughts, or excessive rainfall.
- (g) *A statement of the existence of any disease supposed to be connected with the water supply*, or any other special reason for requiring analysis.

PHYSICAL CHARACTERS OF WATER.

Colour—Should be clear, bright, and not turbid. Although turbidity does not always denote an impure water, still it is always to be regarded with suspicion. The colour of water is ascertained by looking down upon a white surface through a column of water two feet in depth. Water may then seem to be slightly green or blue ; but, if yellow or brown, it is to be regarded with suspicion. A natural water may contain—

In Suspension.—Particles of animals, vegetable or mineral origin. Microbes, and other living organisms, animal and vegetable.

In Solution.—Mineral salts, soluble organic matter of animal and vegetable origin.

Suspended matters can be detected by allowing a sample of water to stand in a tall glass for a day, after which any sediment is to be examined under the microscope. Sand is known by its angular outline, chalk is detected by the addition of acid which dissolves it ; cotton, linen, leaves, and woody fibre are easily recognised. Hair, wool, bits of insects, epithelial scales and round globular bodies, denoting sewage contamination, may be found. Cotton fibres are an important evidence of pollution by household waste or sewage.

Living organisms.—Rhizopoda, Hydrozoa, Rotifera, Scolecida, Entomostraca, Insecta, Fungi, Algae, and Diatomacea are found in water. Infusina (Paramoecium and Vorticella) and Fungi indicate the presence of impurities. Parasites such as tapeworms—Guinea worm—*Dochunis duodenalis*—Bilharzia and leeches may be found as ova or in the adult or embryonic form. To estimate the purity of water, the chemical analysis should be supplemented by a bacteriological examination, and both these examinations should be considered in conjunction with a careful examination of the source of the water and the possible means of pollution. Whilst much must

necessarily depend upon the species of bacteria present in water (pathogenic bacteria rendering water unfit for use, even though present in exceedingly small numbers), the number of bacteria present is useful for gauging the quality of the water. A good potable water ought not to contain more than 100 bacteria per cubic centimetre. Water forms the most natural vehicle for the distribution of bacteria, but the number contained therein varies very much with the source of the water. Stagnant water contains very many micro-organisms, which differ altogether from the numbers found in comparatively pure water, as the latter only contains harmless saprophytes. A suspicious water to show conclusive evidence of contamination, should contain more than 100 bacteria and less than 500, but a bad water contains from 500 up to millions per cubic centimetre. About 240 species of bacteria have already been found in water, the majority being harmless saprophytes, although many pathogenic species are often found. Pathogenic bacteria when introduced into a potable water, retain their vitality for a long time and multiply indefinitely. Thus it will be seen that the virulence of contaminated water is not necessarily dependent on the organic impurity of water, but upon the specific pollution. Care must be observed in the bacteriological examination of samples of water, as a great increase may take place in the number of organisms in a short time.

Most of the microbes found in water multiply very rapidly at ordinary temperatures, especially if the water is impure, and in addition to this increase of the micro-organisms they are constantly being recruited by aerial organisms. The number of bacteria in water is constantly changing, but they can be easily counted by adding a small quantity of the suspected water to a tube containing nutrient gelatine, and cultivating on a glass plate. The colonies can then be counted. The bacteria found in water are moving and motionless, micrococci, bacteria, bacilli

and spirilla. The great majority are perfectly harmless, but pathogenic microbes of cholera, enteric fever, malaria, and anthrax have been found. The bacillus of cholera (*spirillum cholera Asiaticum*) will not live in pure water, but the bacilli of anthrax, though they perish themselves, give off spores which retain their vitality even in distilled water. It is sometimes very difficult to isolate the bacillus of typhoid fever, but the most enthusiastic bacteriologist cannot deny that the specific organism may have been present in a given water supply a week ago, and at the time of examination may have disappeared.

A litre of water can dissolve 25 cc. of oxygen, 46 cc. of nitrogen and 1000 cc. carbonic acid gas at ordinary temperature and pressure. The proportion, however, of these gases is very variable and depends upon the source of water, the degree of pollution and exposure to air, and the vegetable growth. Water from chalky and limestone regions contains an excess of carbonic acid. Potash will absorb the carbonic acid in water; pyrogallate of potash or hyposulphite of soda will take up the oxygen and leave a residue of nitrogen. Sulphuretted hydrogen may be found in water and be due to mineral sulphides, decomposition of sulphates by organic matter, fermentation of vegetable matter in stagnant pools or pollution by coal gas. *Beggiatoa alba* is fungus which has the power of reducing sulphates in water. Aerated waters are bright and agreeable to the palate, and it is the absence of dissolved gases in distilled water which renders it flat and unpleasant to the taste. The *mineral salts* contained in water are derived from the various strata with which the water has been in contact. These salts may be chlorides, sulphates, carbonates, silicates, nitrates, nitrites, phosphates, etc., with bases of lime, soda, magnesia, potash, alumina or iron, but rarely of lead, zinc, copper, manganese or arsenic, although lead, zinc and copper are often derived from vessels in which water is stored or from conduits. In rainwater there are

practically no mineral salts, and in a potable water they should not exceed 400 parts per 1,000,000. Chlorides estimated as common salt may be present in from 10 to 20 parts per million, or they may be absent. According to the American method the presence of chlorides is to be regarded as a sign of contamination; but unless there are other signs of animal pollution the presence of chlorides cannot be altogether regarded as evidence of pollution, for if the source of water supply is near the sea there may be an apparent excess of chlorides present in the water. In other words we may say that if no chlorides are present the water is free from organic pollution, but the presence of chlorides may, or may not, indicate danger according to surrounding evidence.

For instance, a percentage of chlorides in a rain-water tank near the sea will not necessarily indicate pollution, but if of the water in two rain-water tanks in the same coast locality, one indicates more chlorine than the other, that having the excess is probably polluted, unless it can be accounted for, for example, by sea spray lodging on the gathering surface. On the other hand, chlorides in a rain-water tank water, in inland districts almost certainly indicate organic pollution.

Similarly in the case of well or river water, chlorides do not necessarily indicate impurity, as they may be derived from salt beds underground. If, however, of two well-waters (in the same district), containing chlorides, one contains them in excess over the other, such a circumstance is suspicious, and calls for further investigation. At the same time rainfall, may modify this. For example, it has been observed that after rainstorms over a certain district of the Hunter River catchment area, which furnishes the Hunter district water supply, the percentage of chlorides largely increases, presumably because of the existence of salt beds in that district, while rainfall over another (limestone) district of the

catchment materially increases the hardness of the water. Common salt (chloride of sodium) is a regular article of consumption by all animals, man included, and is always present in the wastes from their living bodies and in their decaying remains. Hence its value as an indicator of organic pollution; but the indication must be judged of with knowledge of the conditions involved.

As a qualitative test a solution of nitrate of silver gives a milky haze, with 15 parts of chlorides per million, a turbidity with 60 parts, and a precipitate with 150 parts. The quantitative test is as follows:—Put 50 cubic centimetres of sample water into a white porcelain dish, and add a few drops of potassic bichromate. Into this mixture drop from a burette a solution of argentic nitrate (4.788 grms. per litre) until a faint red tinge appears, showing that the chlorine is exhausted and argentic chromate is beginning to form. Each cubic centimetre of the silver solution corresponds to 0.01 milligram of sodic chloride. If 50 cc. of sample water take X cc. of silver solution before the red tinge appears there, X, multiplied by .01 mgrs. of sodic chloride in the 50 cc. and $X \times .01 \times 20$ mgrms. per litre.

Sulphates are usually calcic and magnesian sulphate, which may cause diarrhoea and dyspepsia. Limestone and dolomite waters, holding 50 to 200 parts of calcic sulphate, are not so wholesome as chalk waters, which contain none. Dolomite water chiefly contains magnesian sulphate. Peaty moorland waters act on lead and form acid sulphate of lead. Sulphates are detected qualitatively by adding a solution of baric chloride with a few drops of hydrochloric acid to a sample of water. A white precipitate indicates 40 parts per million of sulphates. No precipitate, after standing, indicates that there are not any more than 20 parts per million of sulphates present. The exact quantity of sulphates present can be ascertained in the following manner:—Boil 200 cubic centimetres of sample water and add slight excess of baric

chloride solution and a little hydrochloric acid, then boil again and filter, collect, wash, ignite, and weigh the precipitate of baric sulphate; subtract weight of baric sulphate thus obtained from 200 cubic centimetres, and the result is the corresponding proportion of sulphuric acid per litre.

Carbonates occur in water derived from chalky limestone and dolomite. They are precipitated on boiling, but magnesian bicarbonate partially redissolves on cooling.

Nitrates and *Nitrites*, like chlorides, are harmless in themselves, but when found in a water exposed to the risk of pollution may suffice to condemn it for use. Sewage undergoing decomposition usually contains nitrites, and their presence always indicates the necessity for a very careful examination, as they usually are evidences of a more recent and, therefore, more dangerous pollution than can be inferred from the presence of nitrates. Nitrites may be produced by the reducing action of metals. Nitrates are chiefly derived from organic matter by oxidation, and chiefly from that of animal origin, such as manure or sewage. If there is a high percentage of chlorides with an excess of nitrates present in water, there is every probability that such water has been subjected to more or less recent sewage pollution. Half a grain of nitric nitrogen per gallon is the usual limit of permissibility, but some waters contain more than this amount, and still are safe, potable waters. The test for nitrates and nitrites resolved itself into one for "oxidised nitrogen," a term which is equivalent to those of "nitrogen as nitrates and nitrites" and "nitric nitrogen."

Qualitative tests for oxidised nitrogen :—

1. Spread out a 2 per cent. solution of diphenylamine in strong sulphuric acid upon a white porcelain plate. Let a drop of the sample water fall in the centre; if oxidised nitrogen be present, there will be a blue tint after a few seconds.

2. Horsley's test is due to a purple tint appearing and changing to brown. This is obtained by adding 2 cc. pure sulphuric acid to 1 cc. of the sample water and one drop of pyrogallie acid solution.

Quantitative tests for oxidised nitrogen:—The quantity of oxidised nitrogen present in a given sample of water is chiefly measured by the depth of colour produced by certain re-agents.

Tests for Nitrites.—Take 70 cc. of the sample of water to be examined and 70 cc. of distilled water in different tubes. The water to be examined is A, the distilled water is called B. To each of the samples add a few drops of sulphuric acid, and then a certain quantity of potassium solution and starch. If after standing five minutes the sample A strikes a blue colour nitrites are present, and the amount can be ascertained by adding to the sample B drop by drop a standard solution of potassium nitrite till B strikes the same colour as A. If A does not strike any colour add a little zinc dust, and a blue colour will appear if nitrates are present. The amount of nitrates present can be ascertained in the same way as the amount of nitrites by substituting potassium nitrate for the potassium nitrite. The *hardness* of water depends upon the presence in it of more or less of such earthy bases as lime, magnesia, iron, baryta, alumina, &c., and the measure of hardness can be ascertained by Clark's soap test. Soap combines in equivalent proportions with these bases, so that if the soap solution be graduated by a solution of known strength of any kind, it will be of equivalent strength for corresponding solutions of other bases. Hardness, therefore, is estimated by the number of grains of calcic carbonate there may be in each gallon (70,000 grains) water. A certain amount of hardness can be removed by boiling, this is called the *temporary* hardness, and that hardness which remains after boiling is called the *permanent* hardness, the two together being known as the total

hardness. To find the total hardness, take a sample of water in stoppered bottle and run into it sufficient of a standardised soap solution to give a quarter inch fine lather on shaking. To find permanent hardness : Boil a sample of water, and when cold shake with the soap solution till the lather is thick and permanent. The soap solution should always be run in from a graduated tube so as to be certain of the actual strength of solution used, that is if a certain soap solution is so made up that 2.2 cubic centimetres of it will form a lather with 50 cc. of a solution of nitrate of barium, we know that there are so many degrees of hardness in the water, *i.e.*,

2.2 cc, soap solution + 50 cc barium nitrate solution give a lather. We must now deduct .2 cc. as the amount of soap solution required to give a lather with distilled water and we get 2 cc. of soap solution equals 50 cc. barium nitrate solution—5 milligrams of calcium carbonate, hence each cc. of the soap solution equals 2.5 milligrams of calcium carbonate or 2 degrees of hardness. To determine the amount of *free ammonia* in any sample of water add to a sample of water a known amount, say 2 cc. of Nessler's reagent (a saturated solution of mercuric iodide in potassic iodide), and add the same quantity of Nessler's reagent to a sample of distilled water equal in amount to the sample of water to be examined. If with the first water the Nessler strikes a brown colour, then add drop by drop from a graduated tube a standard solution of ammonium chloride solution to the distilled water till the colour reaches the same intensity as it has in the sample of suspected water.

The amount of the ammonium chloride solution is then read off, and as each cc. of the solution represents so much ammonia, the quantity of ammonia which exists in a sample is ascertained. Besides free or uncombined ammonia which may exist in a sample of water, there is also that which exists combined

with organic matter. The test for this is complicated, and students are referred to such test-books as Wanklyn for information. According to Mr. Clowes, one of the most important tests in determining the purity or impurity of water is the determination of its affinity for oxygen. Into a stoppered bottle of 300 cc. capacity, place 250 cc. of the water sample, and heat it to a temperature of 80° F., then run in 10 cc. of dilute sulphuric acid (1 to 3), and 10 cc. of a solution of permanganate of potash (316 gramme in a litre of water). A pink colour will result. Keep the bottle contents at the same heat, and note carefully if the pink colour is discharged, and if it is keep adding the permanganate solution till the colour remains fixed. At the end of 15 minutes add 3 drops of solution of iodide of potash (10 per cent.) and the colour will change to yellow. To this iodine-tinted water add 1 cc. of a solution of starch, and then keep adding a solution of thio-sulphate of soda (1 gramme in 1 litre) till the blue tint disappears, and read off the actual amount of thio-sulphate used. The volume of the thio-sulphate used represents the actual reducing value of thio-sulphate for the precise amount of permanganate used or added in the experiment. *Carbon dioxide* being always absorbed from the atmospheric air, exists always in water. Microscopical and bacteriological examinations are beyond the scope of this work and may be studied in larger text-books. The *hygienic value of a water analysis* is that, although it cannot guarantee us purity and safety, yet it very frequently can reveal to us impurity and risk. Chemical analysis has its use in that it can tell us whether or not the inorganic constituents are unobjectionable in quality and quantity, and that organic matter is absent or barely appreciable. It must not, however, be made the sole arbiter between safety and risk, and the results must always be interpreted in the light afforded by a searching examination of the source of the sample.

To determine the amount of lead present in water the following method is used :—

Prepare a standard solution of *lead acetate* by dissolving $\cdot 183$ gramme of the crystallised salt in distilled water. One cubic centimetre of the solution contains $0\cdot 1$ milligramme of metallic lead. Take 100 cc. of the sample of water and add to it a few drops of acetic acid, and then add $0\cdot 5$ cc. of a saturated solution of ammonium sulphide. If any lead is present a brownish-black colouration will be produced. Compare this with a quantity (100 cc.) of distilled water, to which a few drops of acetic acid and $0\cdot 5$ cc. ammonium sulphide and sufficient of the standard solution of lead have been added to produce the same colouration. From the amount of lead solution used the quantity of lead in the water under examination is readily calculated.

Requirements of Towns and Dwellings. — The quantity of water used varies greatly, the habits of the people, no less than the climate, affecting the matter vitally. It has been found that not only does this principal variation in usage exist, but, beyond that, in every case there is (1st) a seasonal variation, (2nd) a daily variation, and (3rd) an hourly variation. These variations, of course, greatly affect the dimensions or capacity of the means adopted for the storage or supply of water, but they are required in full detail more by the Engineer than the Sanitary Inspector. For the latter, a general knowledge of the facts is all that is needed.

It is acknowledged that from 9 to 12 gallons of water per adult per day is a necessity for even fairly cleanly existence, and this would not allow for baths to the extent desirable in this climate, especially in summer time. Although, however, this total quantity is the minimum for reasonable cleanliness, it must be understood that most of it is needed for washing and cleansing purposes, and but little for actual human consumption. It is important that an Inspector should know this, for, although it is

not desirable if it can be avoided, in some cases it might be necessary to provide a special, or specially purified supply, for cooking and drinking purposes. The balance, to be used for cleansing or washing, being, perhaps, of a nature which could not be passed as sufficiently pure for human usage, but good enough and of sufficient abundance for general use otherwise. For ordinary middle-class houses, the amount of this specially pure supply may be taken at about one gallon per adult per day; and this, indeed, is the British barrack allowance. For houses of the better class this allowance would be insufficient, because of extra cooking; and for smaller class houses it would not be reached. It would, however, be reasonable to insist on one gallon per head per day, as a minimum allowance for sufficient supply for this purpose.

With the requirements of towns, as a whole, the Inspector has nothing to do, and this question is complicated by the supplies for public purposes, such as fountains, fire extinction, manufactures, etc., with which the Inspector has no concern. His duties as regards towns are to see (1st) that the fittings in each house are sufficient, under the existing conditions of supply, to give the minimum quantity of water necessary for health, and (2nd) to see that the source of the supply and the service fittings and store tanks are such that the water will be provided and preserved sufficiently pure for the household usage.

Water supplies may conveniently be divided into two broad classes—private supply and public supply; and each of these may be again subdivided, the former into rain water supply, well supply, and river or creek supply, and the latter into constant and intermittent services.

Taking these in order—

Rain Water Supply: In the provision of a sufficient supply from rainfall, two main points should be looked to—(1st) sufficient storage; and (2nd) the straining of the rain water, from the inevitable roof-

gathered impurities, accompanying the first flow from a shower, and the preservation and delivery of the water in a pure state by the provision of suitably-constructed storage tanks and means of delivery.

The first point, that of sufficient storage, depends on the rainfall of the particular district and the area of gathering ground, which is usually roof surface. The material of the roof covering, and also the nature of the rainfall, influences the matter. For instance, while an iron roof absorbs no part of the rain falling on it, a tile or shingle roof will, when dry, absorb a considerable quantity at the beginning of a shower, but when once wetted no further practical absorption takes place. It follows that with tiles or shingles, and, in a lesser degree, slates, a series of slight showers at intervals would add nothing to the storage, because the whole of the water might be absorbed by the slates, and again evaporated, before the succeeding shower. Under similar circumstances even iron would lose a small percentage of the rainfall in this way, but the quantity would be comparatively trifling. Iron being so largely used for roofing in these colonies, the loss from this source may be neglected when that material is used.

Rainfall, as already explained, is here measured in inches and points. The meaning of this is: the inches and hundredth part of an inch (called points) of *depth* of rain falling over a given *horizontal* area. For instance, if a kerosene tin, with the top cut off, were placed in the open air, with its bottom set perfectly level, the depth of water found in it after a shower, measured in inches and points, would be the measure of the rainfall during that shower. This is because the sides being vertical, this depth would be exactly the depth of water which had fallen *over the area of the bottom*. If, however, the sides of the measuring vessel sloped inwards or outwards, this measure would be obviously incorrect.

The total quantity of rain water available in any case is, therefore, it will be seen, measured by the horizontal area covered by the roofs, multiplied by the depth of rain, falling in that particular district. It should be carefully noted that the *slope* of the roof has nothing to do with the matter, the available gathering surface being the *horizontal* area covered.

In order to estimate the quantity of water available it will be useful to remember that each 100ft. superficial, or "square" of gathering area, represents a quantity of about 52 gallons for every inch of rainfall. Thus, a roof covering a space 40ft. x 40ft. would measure 1600ft. superficial, or 16 squares, so that such a roof would collect 16×52 , or 836 gallons, for each inch of rainfall. Rainfall, as has been already pointed out, varies immensely in different districts of Australia, and, further, the average rainfall cannot be relied on, because in years of drought, such as the year 1888, only half the average may be all that is to be had.

The following interesting table from Mr. Russell's Rain and River Report for 1889 will make this clear and will also be of great value as showing the rainfall actually available in the various parts of New South Wales:—

STATEMENT showing the relation between the Rainfall during the recent years and the average: the average Rainfall in each case depends upon the longest available record.

STATIONS.	Average Rainfall.	No. of Years.	Percentage of Rainfall.									
			1881.		1882.		1883.		1884.		1885.	
			Above	Below	Above	Below	Above	Below	Above	Below	Above	Below
			Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.
Albury ...	Inches.	23	12	17	13	23	9	7	57	...	18	29
Armidade ...	28·36	25	33	16	5	30	23	10	5	...	43	...
Balranald ...	32·55	11	46	15	22	26	4	22	51	...	51	47
Bathurst ...	12·44	32	...	11	10	19	12	3	37	...	38	3
Bourke ...	23·62	18	1	39	38	40	11	15	48	...	57	22
Braidwood ...	16·15	13	...	28	23	15	17	...	47	...	26	...
Cape St. George...	27·19	23	22	1	5	22	43	50	*	...	65	...
Casino ...	50·19	14	...	12	16	...	34	56	52	...	22	33
Casino ...	41·30	14	...	...	...	37	31	47	51	...	22	49
Clarence ...	52·68	12	...	1	7	...	30	25	9	...	53	76
Cobar ...	12·05	9	...	14	42	36	38	65	66	...	33	23
Condobolin ...	19·17	8	...	13	...	5	9	15	42	...	37	8
Cooma ...	19·04	24	1	17	1	23	9	31	46	...	27	26
Coonamble ...	21·72	10	2½	7	29	28	21	31	30	...	56	53
Deniliquin ...	17·06	29	20	*	13	36	2	18	30	...	43	...
Dubbo ...	21·69	18	31	3	35	18	3	81	74	...	34	40

* Equal to Average.

STATION.	Average Rainfall.	No. of Years.	Percentage of Rainfall—(continued).																	
			1881.		1882.		1883.		1884.		1885.		1886.		1887.		1888.		1889.	
			Above.	Below.	Above.	Below.	Above.	Below.	Above.	Below.	Above.	Below.	Above.	Below.	Above.	Below.	Above.	Below.	Average.	
Eden	35.01	20	19	28	25	26	48	12	3	..	53	..	30	24	..	30	9	..		
Forbes	19.91	14	3	15	20	30	9	26	69	..	25	..	27	..	..	25	..	..
Goulburn	26.13	31	18	26	34	36	9	..	34	..	27	..	13	..	..	13	..	..
Grafton	36.12	17	..	20	2	22	23	18	60	..	7	..	..	..	..	..	..	..
Gundabluie	18.16	6	..	..	..	1	..	78	..	..	..	..	..	..	..	..	..	..
Gunnedah	25.03	11	4	..	..	24	30	28	36	..	41	..	36	..	..	36	..	..
Hay	14.76	9	21	3	20	39	14	26	58	..	46	..	25	..	..	25	..	..
Hillston (Roto)	15.80	12	2	1	22	42	6	..	47	..	41	..	82	..	..	82	..	..
Inverell	29.44	13	..	..	5	23	1	50	31	..	19	..	74	..	..	74	..	..
Kiandra	64.80	15	..	..	4	..	46	56	55	..	11	..	39	..	..	39	..	..
Louth	14.79	9	..	5	21	45	..	..	..	..	82	..	58	..	..	58	..	..
Maitland (West)	33.52	22	..	..	..	..	..	10	72	..	43	..	14	..	..	14	..	..
Menindie	9.86	12	24	21	19	29	6	89	84	..	72	..	69	..	..	69	19	..
Milparinka	9.32	8	12	..	35	48	68	2	55	..	77	..	18	..	..	18	..	..
Mount Victoria	35.36	17	..	29	13	7	..	38	47	..	39	..	5	..	..	5	..	..
Mudgee	26.02	16	..	13	19	19	..	48	18	..	39	..	44	..	..	44	..	..
Narrabri	25.04	18	..	1	38	15	..	28	7	..	28	..	33	..	..	33	..	..
Narrandera	18.58	5	..	8	5	22	..	11	25	..	39	..	33	..	..	33	..	..

Percentage of Rainfall - (*continued*).

STATION.	Average Rainfall.	No. of Years.	1881.		1882.		1883.		1884.		1885.		1886.		1887.		1888.		1889.	
			Above	Below	Above	Below	Above	Below	Above	Below	Above	Below	Above	Below	Above	Below	Above	Below	Above	Below
			Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.
	Inches.																			
Newcastle	46.98	28	7	...	39	1	...	10	...	13	...	18	...	34	...	39	...	2	...	
Nynan	18.58	6	...	...	...	...	...	...	...	...	...	...	62	39	...	57	...	34	...
Orange	37.71	18	11	...	15	...	22	34	...	16	...	...	28	44	...	45	...	12	...
Port Macquarie	61.92	27	1	...	19	...	5	23	...	13	...	...	...	101	...	18	...	...	4
Scone	23.35	13	...	...	34	11	...	...	...	7	...	11	...	56	...	54	...	31	...
Sydney	49.23	31	18	...	15	...	6	12	...	20	...	21	...	21	...	53	...	16	...	
Tamworth (West)	26.43	5	...	...	2	...	5	23	...	14	...	4	...	35	...	43	...	36	...
Tenterfield	31.10	19	33	12	...	...	5	...	...	15	...	53	...	44	...	40	...	14	...
Wagga Wagga	22.72	16	...	11	...	...	20	27	...	2	...	11	...	48	...	24	...	27	...
Walgett	19.20	10	34	39	...	...	46	35	...	5	...	83	...	47	...	45	...	67	...
Wanaaring	13.33	9	...	41	...	...	31	30	...	32	...	2	...	70	...	67	...	7	...
Warralda	26.19	8	...	13	...	...	5	30	...	10	...	48	...	26	...	35	...	66	...
Wentworth	11.41	19	25	...	17	...	19	24	...	8	...	2	...	31	...	58	...	73	...	
Wilcannia	12.62	10	...	1	...	...	34	25	...	16	...	17	...	62	...	74	...	10	...
Windsor	31.77	28	...	17	...	...	11	27	...	30	...	33	...	23	...	45	...	23	...
Wollongong	41.77	14	...	*	42	12	...	8	...	27	...	11	...	43	...	37	...	5	...	
Young	26.83	17	23	5	...	...	24	21	...	7	...	8	...	52	...	54	...	12	...
Mean of all Stations	27.09	16.0	...	6.5	...	8.0	17.5	21.3	...	7.2	...	17.5	...	43.5	...	42.4	...	72.1	...	

* Equal to Average.

It will be observed that the year 1887 was a wet year, the rainfall being in every case given, above the average. The following year was a year of drought, the rainfall being in some cases 77 per cent. below the average, while the succeeding year, 1889, was one of rain, on the whole, above the average.

Comparing for our purpose, for example, Sydney as representing the coast district, Bathurst as a type of the western mountain slopes, and Bourke of the inland plains, we find that, taking the *average* rainfall, each 'square' of gathering area represents in the Sydney district 49×52 , or 2548 gallons per year; Bathurst, $23\frac{1}{2} \times 52$, or 1220 gallons; and Bourke, 16×52 , or only 832 gallons. Dividing these figures by the days in the year, we have respectively a possible supply per day of 7 gallons (nearly) at Sydney, 3 $\frac{3}{10}$ ths gallons at Bathurst, and under 2 $\frac{3}{10}$ ths gallons at Bourke. These available supplies, it will be observed, are obtained only, by having tank capacity to store the entire rainfall during a wet year, so as to supply the deficiency during a dry one. For example, referring to the rainfall table given above, it will be obvious that during the year 1888, the available rainfall at Bourke being 57 per cent. under the average, the tank capacity must be large enough to store enough of the *excess* rainfall of previous years, in addition to the regular supply, to provide fully six months' average supply.

It is possible, by making up tables based on the monthly rainfalls for a series of years, to formulate a method, whereby the capacity of tanks required for different water usages and different roof areas, up to the maximum possible, can be exactly determined for different districts. The method would, however, take too much space to describe in a handbook of this kind. It will be sufficient here to state, that while in the Sydney and Bathurst districts, a storage capacity of from eight to ten months' average rainfall over the roof area will be required, in order to obtain

the maximum average supply, throughout a dry year, in Bourke, the capacity would probably not be excessive, if provision were made for the storage of a two years' rainfall.

In estimating the quantity required for any particular establishment, the water needed for cattle, horses, etc., must be, of course, added ; and it should be remembered that, particularly in the case of cows and other animals used for food purposes, it is now recognised that that water must be at least reasonably pure and free from all *dangerous* pollution. It will be sufficient to provide eight gallons per day for each horse and six for each cow, and one gallon for each sheep or pig. Dogs require about half a gallon per day.

In the second point, in regard to rain water supply, the straining or other treatment of the water as it passes from the gathering area to the store tanks is especially important. In the first place, it may be stated at once, that rain water collected from the roofs of houses in large towns, is utterly unsuited for human usage. The air of large towns is at all times so charged with such an excess of floating matter, much of it the organic refuse of habitation, that the rain falling through the air is often impure before it reaches the gathering ground, while the gathering ground not only collects the rain when it falls, but, of course, also, the constantly depositing organic and other dust and dirt from the air. It is for this reason laid down as a sanitary axiom, that water from such a source is not suitable for domestic use.

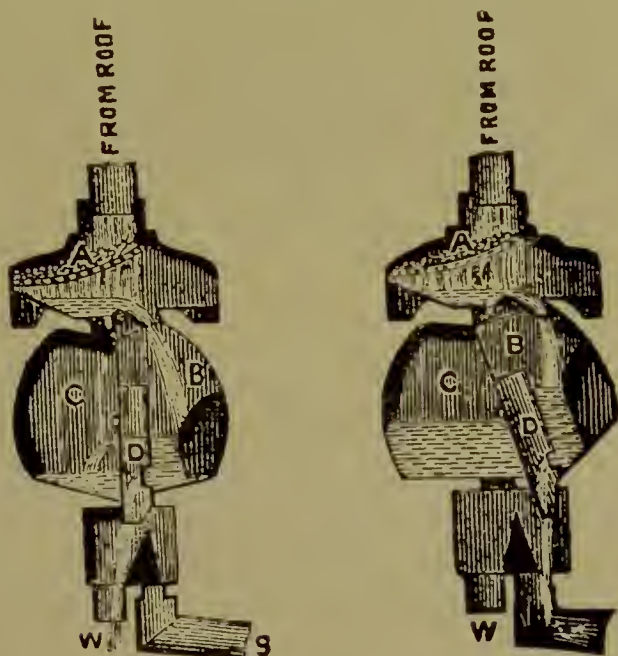
Even in the country, the roofs and gutters become covered during dry periods with organic matter, such as bird droppings, barnyard dust, feathers, leaves, and even dead animals. These are, of course, largely washed down with the collection of the first showers. and unless proper means are taken to prevent it, will find their way into the store tanks, and, of course, pollute the water. All rain water should be at the *very least* strained before passing into the tanks and

yet how seldom is even that imperfect safeguard adopted. The best and safest way is to separate the first rain washings of the roof from the subsequent flow. Of course, when water is so scarce as it is in many parts of the colony, the comparatively impure water, forming the washings of the roof, would not be wasted but would be run into a separate tank and used for what might be called the coarser washing purposes, such as floor and vehicle washing, &c. &c. Mere straining is very far from removing anything but the coarser suspended matter from rainfall water, and a properly constructed filter, sufficiently large, to deal with the sudden flow from an ordinary gathering area during the first heavy rain, is usually out of the question. Separation is, therefore, far the best and simplest method to adopt in nearly all cases.

Like other things in regard to domestic arrangements of this kind, it is practically useless to suggest anything which requires to be attended to specially, particularly, as in this case, at uncertain intervals. An automatic separator is therefore a desideratum, and such an apparatus is fortunately available in what is known as "Roberts' Automatic Rain-water Separator." This machine, which is fixed between the rain pipes and the store tanks is so made that after an amount of water (the quantity of which can be regulated according to the size of the gathering ground) has flowed to the washings tank, the delivery pipe shifts, so as to discharge into the pipe leading to the clean water tanks. Shortly after the rain ceases the apparatus shifts automatically back to its first position, ready again to deliver into the washings tank. The diagram, Fig. 2, will give a better idea of the action. Apparatus of a similar kind have been made which require to be altered by hand, but these are to a large extent useless, because people are not willing to go out in the rain to alter the apparatus to the clear water tank, and when the shower is over the apparatus, if it has been altered at all, is probably left turned on to the clean water and forgotten. This

ROBERTS' RAIN-WATER SEPARATOR.

FIG. 2.



DESCRIPTION.—A, straining grating; B, C, D, swinging portion for altering discharge; w, discharge pipe to waste, or dirty water tank; S, discharge pipe to clean water, or storage tank.

ACTION.—The normal position is that shewn on the left-hand drawing. When rain-water begins to flow from roof, it passes first through the strainer A, and thence into the chamber B. As the water gradually rises in chamber B, part passes by a small hole to chamber C, gradually filling it up, but the bulk of the water discharges through the pipe D, in the first instance, discharging through the pipe w. As C fills up, the weight of the water overbalances the weight of the side B, and the swinging part then tips over into the position shewn on the right-hand drawing, when the now clarified rain-water discharges through the pipe D into the pipe S. When the rain ceases the water in C gradually drains off through the small hole, and, the actuating weight being thus removed, the apparatus tips back into its first position.

means that the next washings are delivered among the clean water, so polluting it. This neglect is especially likely to occur if the showers fall during the night. The only objection to the Roberts' Separator is that, with a close succession of light showers at intervals, more water than necessary may be delivered into the washings tank, as under such circumstances the apparatus may not have time to reverse. In any case the water need not be wasted, and besides, if wished, there are means for locking the delivery in one direction or the other, so that with attention, none of the clean water need be sent into the washings tanks.

Creek Waters.—In many places creek waters are available for water supply. The purity of the water must of course in such cases be determined, and the watershed should be looked to, in order to see that heavy rains may not cause pollution by washing in impurities existing in or on the watershed. The next point to ascertain is the quantity available. This, of course, will vary at different seasons and in different years. This point must be determined by inquiry, as there is seldom time for observations extending over a sufficient period to be reliable. If the creek is a small one the actual flow may be determined with sufficient accuracy in two ways. By both methods it is necessary to block the creek temporarily by an earth dam, which can easily be made by means of a few shovelfuls of earth.

Flow Through a Pipe.—The first method is by observing the height the water rises above the centre of a small horizontal pipe, when the pipe is discharging all the water flowing. This will, of course, be the case when the water ceases to rise behind the dam.

Small pieces of pipe can, usually, easily be obtained. For instance, ordinary red tile drainage pipes are usually 2in. diameter; iron down spouts may be obtained 2in. or 3in. diameter, and ordinary glazed drain-pipes are made 3in., 4in., 6in., or 9in. diameter.

In order to apply this method it will be necessary to note that with the pipe flowing *just* full, a two-inch will discharge about 18 gallons per minute; a three-inch pipe, 50 gallons; a four-inch 112 gallons, and a nine-inch 778 gallons. If the pipes are flowing half full, they will discharge approximately half those quantities, but it should be remembered that this rule only holds true with a *half* full flow, and does not thus apply to quarter or three-quarter full. If the water level behind the dam rises above the level of the pipe, the flow may be approximately determined by remembering the simple rule, that the discharge varies in proportion to the square root of the head: that is, the height of the *surface* of the water *above* the pipe. In order to apply this rule it will be necessary to note the discharge of short pipes under a head of water. Thus, with a head of water of twelve inches, a two-inch pipe will discharge nearly 52 gallons per minute, a three-inch 117 gallons, a four-inch 207 gallons, a six-inch 466 gallons, and a nine-inch 1049 gallons. The flow at other heads can be determined by a simple proportion sum in the manner above indicated.

Flow over a Weir.—The second method of determining the quantity flowing is by observing the depth of the discharge over a horizontal weir. By this method a thin board or a piece of thin iron with a straight top edge is pushed into the earth across the top length of the earth dam, and two flat pieces are pushed into the earth across the ends and rising well above the top edge of the cross stream piece. The dam must then be raised between the end pieces, and the banks, so as to cause all the water to flow over the cross stream piece and between the end pieces. It will also be desirable to place a board or piece of iron, or a few stones on the earth when the water falls over the weir, as otherwise the earth would be washed away, before the full depth of flow over the weir could be measured. The observer then waits till the depth of flow over the edge of the

board ceases to increase. The quantity flowing can then be determined from the depth of water over the weir, and the length of the edge over which the water is flowing as follows:—It should first be noted that the water will have more or less slope towards the weir, and the “depth” of water over the weir is the height of the top of the surface of this slope above the top edge of the weir, and not the depth on top of the weir, which would give less than is really flowing.

Having determined this height, the quantity can be obtained from the following figures:—For each foot *width* along the crest of the weir the following heights will give the named discharge in cubic feet per minute:—For 1 inch height above weir, 5 cubic feet per minute; $1\frac{1}{2}$ inches, $9\frac{1}{2}$; 2 inches, $14\frac{1}{2}$; $2\frac{1}{2}$ inches, $20\frac{3}{4}$; 3 inches, $26\frac{3}{4}$; $3\frac{1}{2}$ inches, $33\frac{3}{4}$; 4 inches, $41\frac{1}{4}$; $4\frac{1}{2}$ inches, 49; 5 inches, $57\frac{1}{2}$; $5\frac{1}{2}$ inches, $66\frac{1}{4}$; 6 inches, $75\frac{3}{4}$. For depths of flow of over $1\frac{1}{2}$ or 2 inches, it will be found difficult to prevent the earth washing away in a temporary earth dam, with makeshift protection to the earth. In any case, the depth of flow above the crest of the weir should never exceed one-tenth of the length of the weir edge, otherwise the above figures will be too inaccurate to be of any practical use. It is, therefore, for every reason better to make the weir long enough to give a flow over it not exceeding two inches at most. Of course, the weir crest must be set perfectly level, so as to ensure that the water shall flow evenly over it, and the drop of the water over its edge should be at least *twice* the height of the height of the water over it. It is important to determine the actual quantity in this way with some approach to accuracy, not only to find out if the supply for household purposes is sufficient, but, in certain cases, to ascertain if certain water-raising machines (such for example, as a hydraulic ram) will have sufficient water-flow power, to enable them to raise the quantity needed to the height required.

The reader will observe that either of those methods of measurement can also be applied in many cases to springs. To judge of the quantity of water flowing, by merely looking at the stream, as is often done, is utterly misleading and should never be relied on. In small flows the quantity can often be ascertained by observing the time taken to fill a vessel of known capacity. In this connection it will be useful to remember the following rules, some of which also apply to the measurement of the capacity of tanks of the usual circular or rectangular form, and of rooms, etc.

Measurement of Areas and Capacities.—One cubic foot of water is equal to about $6\frac{1}{4}$ gallons, and one gallon of water measures $\cdot 16$ cubic feet. Hence, to convert cubic feet into gallons multiply by $6\frac{1}{4}$, and to convert gallons into cubic feet multiply by $\cdot 16$. One gallon of fresh water weighs 10 lbs., and one cubic inch $\cdot 03612$ lbs.

An ordinary bucket is often available as a measuring vessel. In order to obtain its capacity, the following formula may be used:—

$$C = \left\{ D^2 \times d^2 + (D \times d) \right\} \times \cdot 7854 \times \frac{1}{3} \text{ of } H$$

When C = Capacity

D = Diameter at top of bucket

d = Diameter at bottom of bucket

H = The vertical height or depth.

The capacity C will be in cubic inches or cubic feet, according as the dimensions D , d , and H are taken in inches or feet, and the gallons can be obtained in either case from the figures given above. An ordinary bucket is simply the frustrum of a cone—that is, a cone with the top cut off, so that the formula given will apply to any vessel of similar shape, or to a circular tank with sloping sides.

To find the contents of a cylindrical vessel, such as an oil drum or an ordinary circular tank, and which also applies to a well, the formula is—

$$C = D^2 \times .7854 \times H$$

When C = Contents in cubic feet

D = Diameter in feet

H = Height or depth in feet.

This gives the contents in cubic feet, but the contents in gallons may be obtained directly by using the formula G or gallons $= D^2 \times H \times 4.9$, D and H being as above stated. In the above formula the dimensions are given in feet, but for small vessels the following rule, when the dimensions are given in inches, will be more convenient. This rule will also apply to the contents of pipes, and, incidentally, to the amount of water thrown by pumps, if the diameter of the pump barrel, length of stroke, and number of strokes in a given time are known. The formula is— $G = D^2 \times H \times .002833$, when D is the diameter, and H the height, length, or stroke, both in inches. The contents of any vessel with vertical sides is obtained by multiplying the area of the bottom by the vertical height, and this also applies to rooms or spaces having the bottom and top surfaces flat and horizontal. It is, therefore, of much importance to know how to calculate the area of variously shaped spaces. The following may be mentioned:—Area of a circle; diameter squared and multiplied by .7854; area of an ellipse; the cross diameters multiplied together and by .7854; area of a triangle of any shape, half the length of one side multiplied by the length of the line measured from the opposite angle to that side, and at right angles to that side.

Regular polygons are figures having three or more equal sides, such as the square (four sides), the octagon (eight sides), etc., etc. It will be seen that all such figures are made up simply of groups of similar triangles equal in number to the sides, and formed by drawing lines from the angles to the centre of the figure. Thus, a square may be cut up in this way by drawing diagonals from corner to corner, and consists of four equal triangles, and an octagon may

be similarly divided into eight triangles, and so on. This being so, clearly the area of any polygon can be found by calculating the area of any one of these triangles and multiplying that by the number of triangles which make up the figure, or, in other words, by the number of sides. This method, although easy to remember and apply, is somewhat lengthy in working out; and the following figures, or constants, as they are called, will much simplify and shorten the process.

The rule is: Multiply one of the sides by itself (that is, square it), and by the constant applicable to the particular polygon. The constants are: For a triagon (a triangle having three equal sides) 4330, for a square (four equal sides) 1.0000, a pentagon (five equal sides) 1.7205, a hexagon (six equal sides) 2.5980, an octagon (eight equal sides) 4.8284.

It is worthy of note, that of the regular polygons, that having the largest number of sides, has the greatest area for the same length of enclosing sides, and the circle, which is the figure having the largest area considered in this way, may be described as a regular polygon having an infinite number of equal sides. Further, the regular polygon which has the largest number of sides and which may be placed or packed side by side without wasting space, is the hexagon or six-sided figure, that of the honeycomb. The bees have, therefore, adopted the shape of tank which, without losing any space between, gives the greatest capacity for the smallest quantity of material used. These constants will be found of use in many ways. For example, a very common form of bay or oriel window in rooms is that of the semi-octagon. If, therefore, an inspector has to ascertain the cubic capacity of such a recess; measuring one full side he finds it to be, say, 4 feet. He then arrives at the area as follows:—Area = $4 \times 4 \times 4.8284$ which equals 77.2544, and that halved or divided by 2 gives 38.6272 superficial feet. This multiplied by the height (if floor and ceiling are flat) gives the con-

tents of the recess in cubic feet. In calculating the area of segments of a circle, a semi-circular or half-circle segment is half the area of the circle of which it forms a part, and that divided by a vertical line in the centre of the diameter or chord, again divides the area into two equal parts, each, of course, one fourth of the area of the complete circle. This is useful to remember in calculating the cubic contents of rooms having semi circular ceilings or quarter circle coves with flat end walls. The calculating of the areas of segments less than a semi-circle, or flat segments, as in the case of rooms having what are often called flat circular ceilings, is, however, more difficult.

If the height of the centre of the ceiling above the chord does not exceed one-eighth of the length of the chord, the following rule gives a very close approximation to the area:—Multiply the length of the chord by the height above the chord, and take two-thirds of the product. If, however, the height is greater than one-eighth of the chord, the following formula gives a result which will not vary from the truth by more than one part in 800 parts:—

Area of segment equals:—

$$1\frac{1}{3}\text{rd. the height} \times \sqrt{\left(\frac{\text{chord}^2}{4}\right)} + (\text{height}^2 \times .388)$$

For finding the capacity of figures not having vertical sides, the three following rules will supply the Inspector with all the data he is likely to require. The first two rules deal with spheres and segments of spheres, and the third is what is called the Prismoidal formula. This will enable the calculation of the capacity of any figure bounded by flat sides, two of which are opposite and parallel. The enclosing sides connecting these two flat and parallel ends may also be curved along a section parallel to the flat sides, provided the curves are such that they form straight lines throughout, between some points on the edges of the parallel sides. This formula could, for instance, be applied, instead of the one already given, in calculating the capacity of an

ordinary bucket; and it could likewise be used in obtaining the capacity of a water tank with sloping sides, provided the bottom was level, for the contents of a heap of road metal, if the top surface was level and it stood on level ground, or for the cubic capacity of a room or part of a room with straight sloping sides all round, provided the upper and lower boundaries of the space were flat and parallel.

The first rule gives the formula for the capacity of a sphere. It is:—Cube the diameter (that is, multiply it twice by itself), and multiply by $\cdot 5236$. The capacity of a hemisphere or hemispherical segment is half that of the sphere, but segments of less than a hemisphere require the following (the second) rule to ascertain their capacity:—Square (that is, multiply by itself) half the diameter of the segment at its springing level, and multiply by 3. To the product add the square of the vertical height from the level of the springing line to the centre or highest point; multiply the sum by the same height, and by $\cdot 5236$.

The third rule is the Prismoidal formula, already partly described. It is as follows:—Add together the areas of the two parallel and opposite sides, and four times the area of the section taken half-way between them and parallel to them; multiply the sum by the perpendicular distance between the two parallel sides, and divide the product by 6.

In concluding this part of the work, it might be mentioned, that the capacity of any cone or pyramid, whether upright or oblique, is found, by multiplying the area of its base, by one-third of the vertical height from the plane of its base to its apex.

These rules and constants will furnish all the data needed to calculate the capacities of the vessels, tanks, and spaces likely to be met with in the work of the Sanitary Inspector.

Returning now to the question of water supply. A creek or spring may sometimes be available at such a

height, that it can be conveyed by gravitation to the point of usage, and the same may occasionally occur in the case of an artesian well, but in most such cases, the water has to be raised by mechanical power of some kind. It will be well, therefore, at this point, to describe shortly, some of the most commonly used methods of doing this. In by far the largest number of cases, pumps of some kind are used, actuated by either man, horse, water, wind, or steam power.

In order, properly to understand about the quantity of water, which can be raised to the point of usage by the employment of any one of these powers, it is necessary, first, to know the method by which such power can be estimated.

The Unit of Work.—Just as in measuring lengths, we require some unit to measure by, such as the inch, the foot or the yard, so as in measuring power, we require a unit of measurement, which can be applied in determining the work possible in any case. In British and American communities, the same unit measure of work is commonly adopted. This is called the “foot-pound” and may be defined as the work done in raising 1lb weight, 1ft. high against the force of gravity. Thus 100ft. lbs. of work may mean the raising of 1lb. weight 100ft. high, or 100lbs. 1ft. high, or 10lbs. 10ft. high. In short, the weight multiplied by the height lifted in feet is the measure of the work done stated in foot pounds. It is by this measure that the work possible to be done by men, animals, and engines of various kinds is estimated, and in such cases a time period is stated. Thus the “horse-power,” used in measuring the power of engines, is defined, as 33,000 ft. lbs. per minute, and is the work which a very powerful horse can exert throughout an eight-hour day's work, with intervals of rest in addition. A man-power is often stated similarly at 3000 ft. lbs. per minute for eight hours' work, but this could be done only by a very powerful man. For short

periods of great exertion much more work can be done, but this, of course, cannot be kept up throughout a day, but only for a few minutes at a time. The following table, quoted from Professor Rankine, from actual trials, will give a clear idea of what may fairly be relied on :—

TABLE OF WORK DONE BY MEN AND HORSES.

Nature of Work and Power.	Drag or Pressure Exerted.	Speed at which the Drag or Pressure is exerted.	Period during which work is kept up.	Foot lbs. per minute.
Man turning crank	13·0lbs.	2·5ft. per sec.	8 hours	2,700
Man turning crank	20·0 ,,	14·4ft. ,,	2 min.	17,280
Man working pump	13·2 ,,	2·5ft. ,,	10 hours	1,980
Draught horse drawing canal boat	120·0 ,,	3·6ft. ,,	8 hours	25,920
Trotting horse drawing carr'ge	30·5 ,,	14 $\frac{2}{3}$ ft. ,, 10 miles per hr.	4 hours	26,850

This table is of great value in estimating the power possible in pumping, and from that, the sufficiency or otherwise of the water supply available with the power provided. The method of doing this is simple. As already stated, a gallon of fresh water weighs 10 lbs., so that to lift every gallon of water, every foot high, requires the expenditure of 10 foot-lbs. of work. To this must be added an allowance for the friction of the machine, and also the friction of the water in flowing through the pump, valves, and pipes. This allowance in a well-made hand-pump, with pipes of sufficient size, should not exceed 10 per cent., so that we may estimate roughly that 11 foot-lbs. of work is required per gallon per foot lift. For example: If a supply of four gallons per minute, required to be pumped to a height of 100 feet, this would require $11 \times 4 \times 100 = 4400$ foot-lbs. per minute, which would be far above the power of a

man. An ordinary hand-pump would therefore be condemned as insufficient to furnish such a supply. Another useful rule is, that for equal powers, the higher the water has to be lifted, the smaller should be the diameter of the pumps. The following table, abstracted from "Hurst," will be of service as a guide in this:—

PUMPS.

Diameter of Pump Suited for Height Lifted.	Gallons which can be Raised per Hour.	Maximum Height the Water should be lifted per unit of the power named.		
		Man with Crank.	Horse with Gin.	1 Horse - power Steam or other Engine.
2 inches	225	80 feet	560 feet	880 feet
2½ "	360	50 "	350 "	550 "
3 "	520	35 "	245 "	385 "
3½ "	700	25 "	175 "	275 "
4 "	900	20 "	140 "	220 "

In the above table the man power is taken at 3000ft.-lbs. per minute the horse with gin at 21,000, and the steam, &c., engine at 33,000.

Windmills are often used for pumping purposes, and their action being dependent on the wind, is of course uncertain. As a general guide it may be mentioned that the Goodhue American windmills are estimated by their makers to average the following powers:—

10 foot diameter wheel about 4000ft.-lbs. per minute, or about $\frac{1}{8}$ h.p.

12 foot diameter wheel about 7000ft.-lbs. per minute, or about $\frac{1}{5}$ th h.p.

14 foot diameter wheel about 11,000ft.-lbs. per minute, or about $\frac{1}{3}$ h.p.

17 foot diameter wheel about 15,000ft.-lbs. per minute, or about $\frac{1}{2}$ h.p.

For a 10 foot wheel lifting water from 10 to 20 feet high the pumps are proportioned as follow to give 20 gallons per minute.

9 inch stroke has a diameter of 4 inches.

7 inch stroke has a diameter of $4\frac{1}{2}$ inches.

5 inch stroke has a diameter of $5\frac{1}{2}$ inches.

4 inch stroke has a diameter of 6 inches.

What is called the *hydraulic ram for pumping water*, (Fig. 4) is not nearly so much used in these colonies as it ought to be. Whenever a flowing creek is available with sufficient fall to give three or four feet of head or drop of the water, there, a hydraulic ram can be fitted, and will work night and day from year's end to year's end practically without attention. It has this great advantage over the windmill, in that, given a constant flow of water, it works regularly and without intermission, and is so more reliable than the windmill. Its efficiency is from 65 to 75 per cent., that is to say, that out of every 100 foot-lbs. of power supplied to it by the running water, it utilizes in pumping water from 65 to 75 foot-lbs. This is easily applied to the practical work of the inspector. Thus, just as it takes 10 foot-lbs. of work to raise 1 gallon of water 1 foot high, irrespective of friction, so 1 gallon of water falling 1 foot, will do work equivalent to 10 foot-lbs. If then we, by gauging a stream, as it is called, find that there is a flow per minute of 30 gallons, and that this flow can be dammed back so as to give a 5-foot fall; here then we have 10 foot-lbs. x 5 x 30 or 1500 foot-lbs. per minute. Seventy per cent of that is 1050 foot-lbs. available for pumping part of the flowing water. If the height the water is to be lifted, is, say, 100 feet, we have then $\frac{1,500 \text{ ft.-lbs.}}{100 \text{ feet.}} = 15 \text{ lbs.}$ which can be lifted by this power 100 feet high, which is equal to $\frac{15}{160}$ ths or 1.5 gallons per minute. This seems a small quantity, but when it is considered

that the delivery is constant, it means 2160 gallons per twenty-four hours. This forms a regular supply, sufficient for seventy-two persons, at thirty gallons per head per day, an allowance ample for all purposes, including the free use of baths.

It would be out of place here fully to describe the working of a hydraulic ram. It will be sufficient to explain that its principle is, that by allowing the water alternately to flow through a pipe, and then suddenly block its flow, the weight and velocity of the water is so caused to give a blow within the pipe, which, on each occasion of the stoppage, forces a portion of the water into the pipe leading to the elevated point, from which it is to be drawn for use. It will thus be seen that the flow of water is not interfered with, only that portion withdrawn to supply the house being lost for use to those further down the stream.

The following table gives examples of hydraulic rams as fitted up in these colonies by Messrs. John Danks & Sons, Limited, to whom we are indebted for the information :—

List Number of Ram.	Actuating Fall or Drop of Flowing Water.	Height to which Water is Lifted.	Length of Discharge Pipe.	Size of Discharge Pipe.	Gallons Pumped per Twenty-four Hours.
No. 4	20.0 feet	150 feet	900 feet	$\frac{3}{4}$ inch	800 gals.
„ 5	11.0 „	125 „	1250 „	$\frac{3}{4}$ „	850 „
„ 7	8.0 „	35 „	400 „	1 $\frac{1}{4}$ „	3500 „
„ 10	6.8 „	104 $\frac{2}{5}$ „	1510 „	2 „	1700 „
„ 7	4.0 „	62 „	1250 „	2 & 1 $\frac{1}{2}$ in	1680 „
„ 6	10.0 „	70 „	547 „	1 $\frac{1}{4}$ inch	1440 „
„ 5	23.9 „	150 $\frac{1}{2}$ „	864 „	1 „	1632 „
„ 6	17.0 „	60 „	550 „	1 $\frac{1}{2}$ „	4800 „

Ordinary Pumps.—There are one or two points in the working of ordinary pumps which it is desirable for the sanitary inspector to know, as, for example, the difference in working, between what are commonly called the suction, and the suction and force pumps. The former have the pump part placed above the surface of the ground, and the pumped water runs

out of a nozzle in the side of the pump. The latter may be on the surface of the ground, or some distance under, and the point of discharge of the water may be at a cistern or tank many feet above the level of the pump. In the latter type, the portion from the pump, down to the level of the water to be pumped, is called the suction part, and works on the same principle, and is subject to the same laws, as the ordinary suction pump. The part from the pump, up to the point of discharge of the pumped water is termed the force pump part. The important difference between these two parts is, that, while the so-called suction part is dependent for its working on the pressure of the atmosphere in relation to the weight of the liquid being pumped, the force part is entirely independent of atmospheric pressure, being limited in its height of lift only, by the power available to work the pump, and the strength of the pipes and fittings. The practical influence of these facts is this—that as the pressure of the atmosphere at the sea level can in practice cause the fresh water to rise only to a height of about 28 feet, if the suction part of the pump is more than that height above the surface of the water, it will not work properly, if at all. Hence, if the surface of the water in a well is 40 feet from the surface of the ground, the pump must be placed at least 12 feet below the ground level, and is better to be placed *just above* the highest level of the water in the well. Further, as the pressure of the atmosphere decreases roughly about 1-30th for every 1000 feet of elevation, it follows, that the safe limit of 28 feet lift for a suction pump must be reduced by 1-30th for every 1000 feet the locality is above the sea level. This of course limits the depth to which the ordinary suction pump can be applied, and in many cases necessitates the use of the more expensive suction and force pump. When the level of the water is such that a suction pump can be employed, that form known as the Abyssinian tube well, is an excellent

one to adopt. This prevents the fouling of the water by surface infiltrations, to which, improperly constructed wells are so liable. It consists of a tube of the ordinary wrought iron type, pointed with a strong steel point screwed into the end, and the upper part of this point part perforated, so as to allow the water access to the pipe. This is driven down into the ground, fresh lengths of pipe being screwed on until the water is reached. An ordinary suction pump is then screwed on to the top, and the water pumped up in the ordinary way. It will be seen that the pipe thus forms an impermeable lining to what is really the well, so that the access of dirty surface-water to the water supply is impossible.

In the construction of *ordinary wells* this is really the chief point to be attended to, and for this purpose, it is necessary to provide a perfectly water-tight lining to the well for a considerable distance below the surface of the ground, and also to carry up this lining for a sufficient distance above the ground level, to prevent the possibility of surface water flowing over the edge of the well into the contained water. For the same reason, the well should have a water-tight cover, and it is also desirable to pave or otherwise protect the ground surface for some distance around the well.

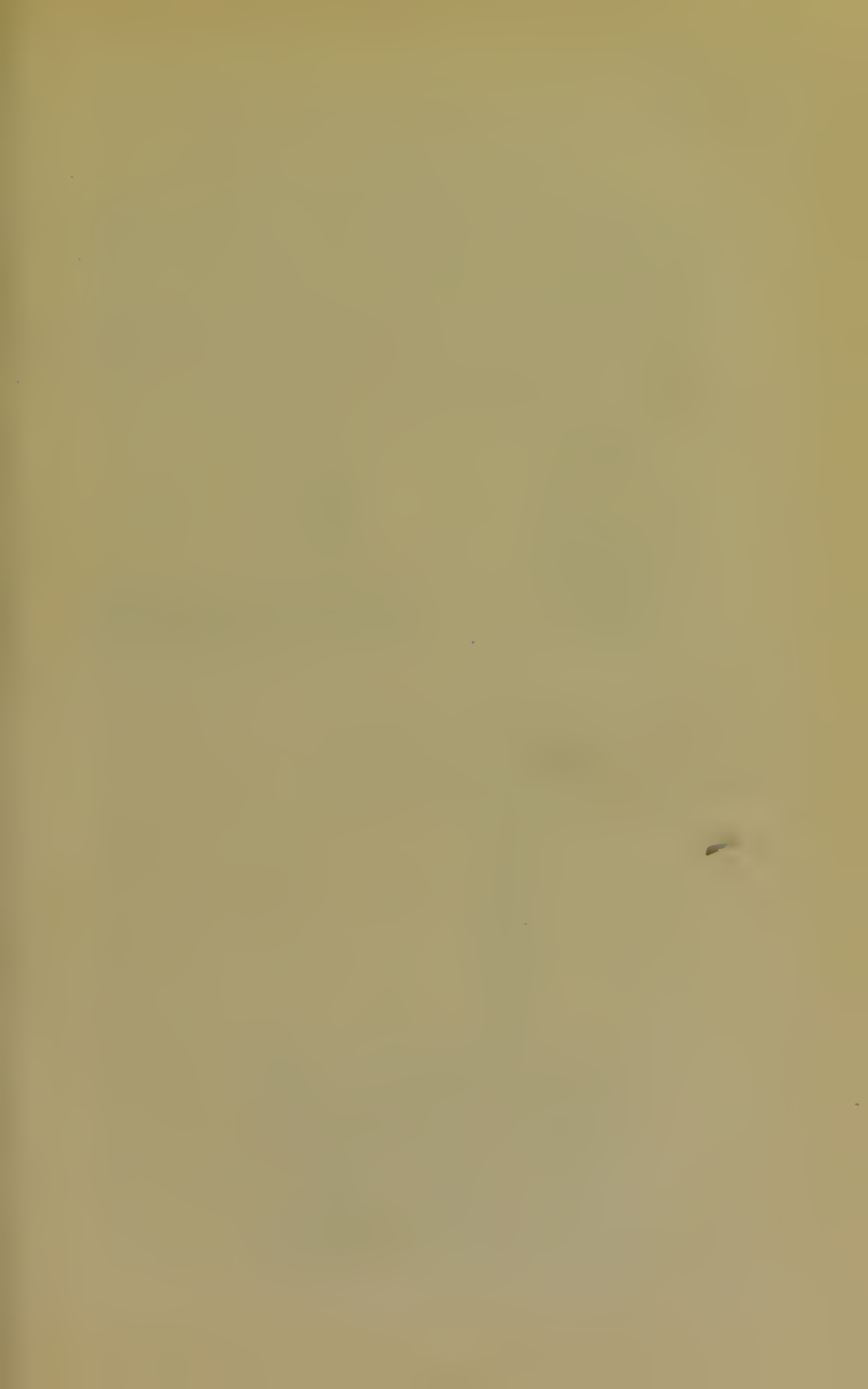
Underground tanks, unless cut out in perfectly impervious material, should also be similarly protected, and, in every case, should be domed over in good material, such as brick-work in cement, or cement concrete, made perfectly impervious to surface infiltration. These dome tops should have a central eye, carried well above the surface, with a movable, but tightly-fitting cover, forming an access for cleaning out the tank, and provided with grated ventilators, also placed well above the ground surface.

Wherever it can be done an emptying pipe should be provided, as this greatly facilitates the cleaning out of the tank, an operation which should always be performed periodically. Such a pipe is seldom

possible in the case of underground tanks, but can, and should, always be provided when the tanks are above the surface. In these colonies, black or galvanized iron is the material almost universally used for store tanks above ground. This material is suitable for the purpose, but such tanks should be periodically emptied, cleaned, and lime or cement-washed inside. This will not only preserve the water pure, but will tend to protect the iron from the corroding action of the water and air, a point which is especially necessary in the case of black iron when used in situations in the neighbourhood of the sea coast.

All tanks made of material liable to decay, such as wooden casks, and the like, are most undesirable. They are seldom properly covered, and in any case are more difficult to keep clean, and more liable generally to pollute the water stored in them.

Public Water Supplies.—When public water supplies are provided, the water is generally fairly pure, but there are several sources of possible pollution even before it reaches the consumer. The question of efficient filtration, when that is necessary, will be dealt with separately, but in the delivery through the street mains, there are two sources particularly, from which danger may arise. These are, the tapping of mains for new connections, and ball fire hydrants if placed in improper positions. The danger in both cases arises when the water is turned off for tapping or repair, etc., and is caused in this way: If the street mains are laid on sloping ground, and the cut-off valve is at the higher end, when the water is turned off, of course supply ceases, but under certain circumstances water may still be obtained by householders at the lower end. It is a well-known fact, that liquid cannot be drawn from a cask by a tap at the lower side, unless a spile hole, as it is called, is made in the upper side of the cask, in order to allow access of air to the surface of the water. Now, a water-main, such as above described, is like the cask,

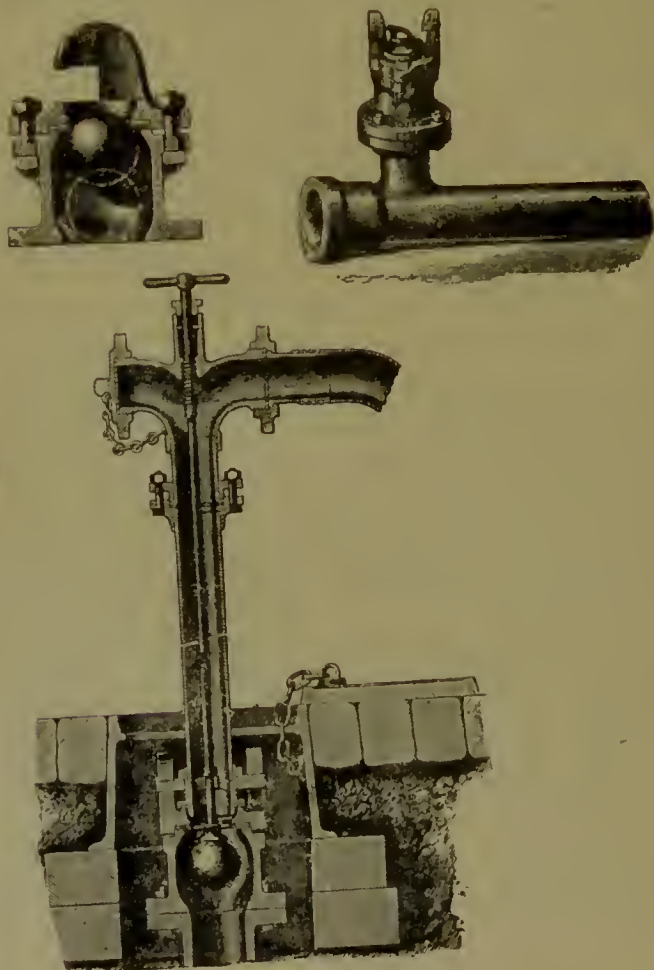


BALL HYDRANT AND STAND PIPE.

FIG. 3.

DESCRIPTION.—The first illustration shows the ball hydrant with ball closed against seat by the water pressure; the dotted circle shows position of ball when any suction takes place. The second illustration shows a ball hydrant with stand pipe fixed, and the ball pushed down against pressure by the opening rod, and the hydrant so opened.

The third illustration shows the position of the ball hydrant in relation to the main pipe, and also a safety cap which is sometimes fitted with a view to prevent the drawing-in of dirty water to the mains when suction takes place.



and the householder's tap at the lower end like the draw-off cock. Thus, although the main is full of water, none can flow out unless a hole is made at the upper end. This means that there is a strong suction towards the inside of the pipe at the upper end. It is thus evident, that if a hole is bored in such a pipe near the upper end of the street main for the purpose of making a new connection to some house, the moment the opening is made, all the taps lower down the street will have water which will last till the pipe empties down to that level. The danger is, that there is thus an immediate rush of air into the inside of the pipe, and if the excavation happens to be full of dirty water, as is often the case, that is inevitably drawn into the pipe, and, of course, pollutes the water, it may be, dangerously. Clearly, also, for the same reason, any leak which happens to exist in this higher section of the pipe, becomes an inlet for ground water, instead of a leak outwards. In the case of ball hydrants, their construction, which will be understood from Fig. 3, is such as to provide a large opening to the pipe the moment any suction occurs. The ball, which closes the opening to the pipe, which is kept in its position only by the pressure of the water outwards, of course immediately falls down the moment the pressure is inwards, and affords easy ingress to any dirty water lying in the hydrant-box, which is always below the level of the street, and often very near the gutters. Indeed, there was a case not long ago in an Australian city, where such hydrants were found to be actually in the street gutters, and as the city was unsewered, and the gutters, therefore, conveyed away the slop and other waters, the condition of things whenever the water was turned off was most dangerous. It is because of these, among other dangers, that the system of intermittent public water supply is condemned. It will be understood that in intermittent water supply, the water is turned on only for a certain period each day, and then turned

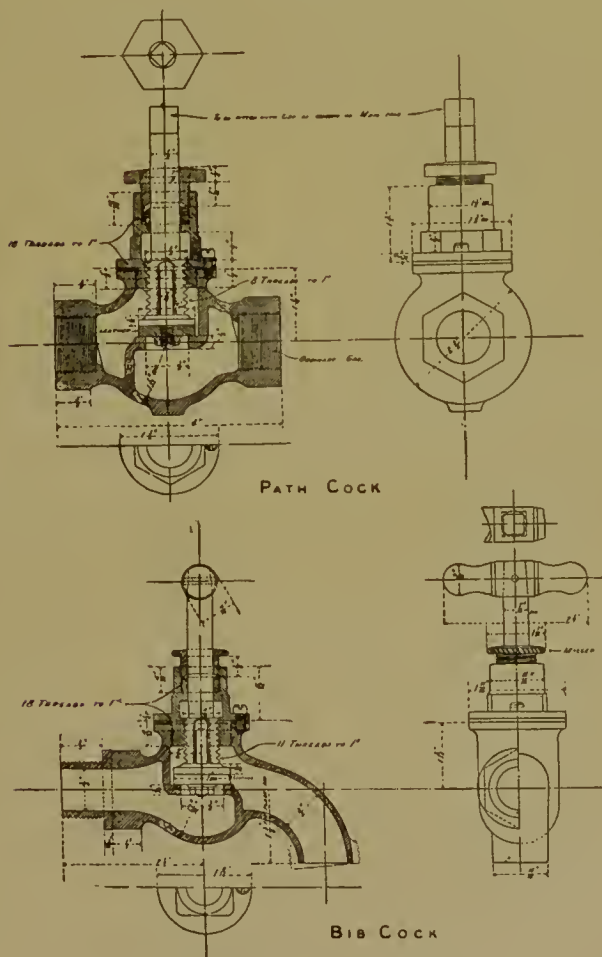
off till the following day. The conditions described are, therefore, set up for the greater part of each 24 hours, and in this way an often most dangerous state of matters created. Even with constant supply, however, the same conditions are established for shorter periods at longer intervals, by the turning off of the water to enable repairs and tappings to be made, and it is recognised that as this is inevitable, means must be taken to minimise the dangers so arising as much as possible. For this reason ball fire hydrants are now condemned and others substituted, which do not open in the way described. What is called, tapping mains under pressure, is also being introduced. That means an arrangement whereby the necessary boring of the street mains, and the fitting of the house branch taps can be accomplished without turning off the water in the pipes. In regard to the house services and internal water supply fitting, several points should be noted.

Water Services.—In the most advanced communities, what are called loose valve-cocks and taps are insisted on. These, by their actions, prevent the possibility of dirty water or foul air being drawn back into the water supply pipes. They are in reality of the same nature as what are called reflux valves, and the drawing Fig. 5 will enable their construction to be understood. These are of the type known as “screw-down” cocks, as distinguished from what are called plug-cocks; that is to say, the cock requires several turns of the handle in order to open or shut it. This has the effect of actuating the valve slowly, and so preventing the sudden shock technically called water hammer, which would occur if the flow of water were suddenly arrested, as in the plug-cock, which closes entirely with one-quarter turn of the handle. This water hammer, besides being objectionable because of the noise, is very apt to cause leakage by damage to the pipes or fittings due to the sudden shock, and so lead to fouling of the water when suction occurs. In the

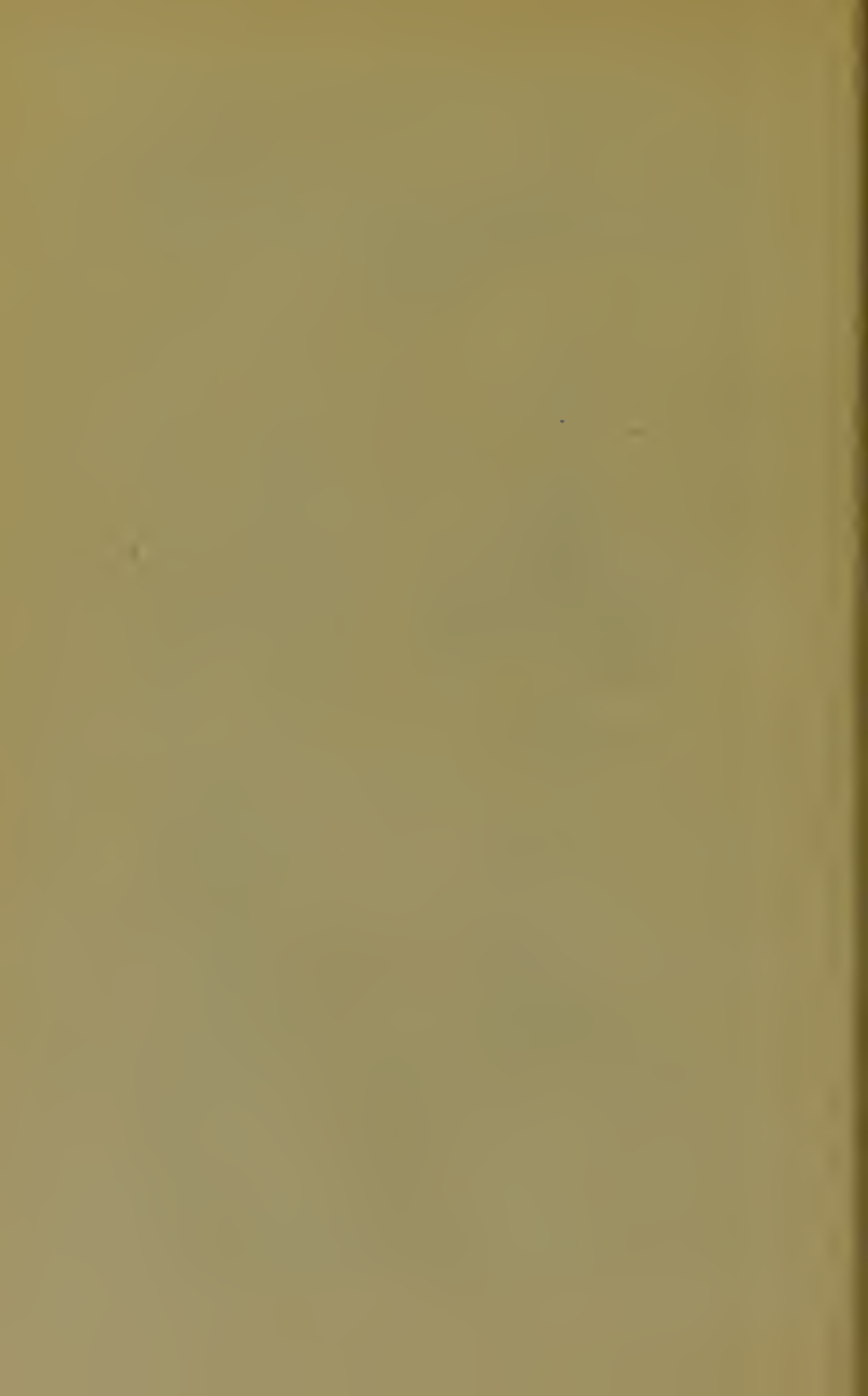
SECTIONS, PLANS, AND ELEVATIONS OF LOOSE VALVE SCREW-DOWN WATER COCKS

(As approved by the Sydney Board of Water Supply and
Sewerage.)

FIG. 5.



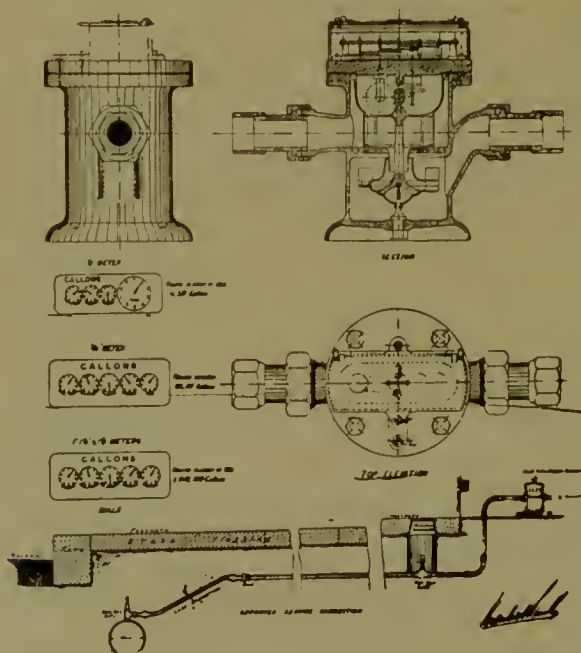
(For description see letterpress).



ARRANGEMENT OF WATER SERVICE AND DRAWINGS OF WATER METER

(Approved by the Sydney Board of Water Supply and Sewerage).

FIG. 6.



DESCRIPTION.—The meter is of what is known as the inferential class. The drawings shew the arrangement and reading of the dials for different sizes of meters. The meter is designated by the size of the pipe on which it is fitted. The approved service connection is shewn by a cross section through the water main and footpath to the house fence.

loose valve-cock, the valve or washer which closes the water-way, is attached loosely to the screw-down or closing spindle, and closes against the direction of the water-flow. The effect of this is, that, in opening the tap when the spindle is turned so as to raise it, the loose valve remains resting on the opening, which it closes, unless the water is turned on in the supply pipes, when the water pressure pushes it up, and the water obtains egress. It will thus be seen that, if a suction exists when the opening handle is actuated, the loose valve nevertheless remains pulled by the suction hard against its seat; so effectually preventing foul gases or dirty water from being drawn back into the pipe, and if the cock is open when the suction occurs, the same effect is produced, for the loose valve whenever the water pressure ceases, drops down on its seat, and subsequent suction only squeezes it more firmly into its place. These valves, therefore, furnish a most efficient safeguard against pollution of the water supply, and one at least should always be interposed between the street mains, and the house service pipes. Under the Sydney rules, two such safeguards are introduced in that position, the "main-cock," which is screwed into the street main, and the "path-cock," which is fixed just outside the boundary of the premises being supplied, and in addition, all the stop-cocks and bib-cocks within the premises are required to be of the loose valve screw-down type. It should be noted, as is evident from their construction, that these valves can act with absolute certainty *only* when the actuating spindle is vertical. The drawing, Fig. 6, shows the arrangement adopted in Sydney. In this case, the service pipes are of galvanised wrought iron, except a short length next the main-cock, which is of lead. This length of lead pipe is required in order to give a certain amount of play to the rigid iron pipes, so as to avoid fracture by any settlement, or expansion and contraction which might occur. Where lead is objectionable, as in the case of some waters which dissolve lead freely,

the same object may be attained by using what is called lead-encased tin pipe, or by introducing in the same position, two or three feet of iron pipes bent twice horizontally at right angles, which forms a sort of spring lengthwise, and gives the necessary flexibility vertically.

Cisterns.—Within the house, the inspector should look particularly to the position and construction of the cistern, and especially to what are called the over-flow pipes, which are required in all cisterns in order to guard against the water running over, and so causing damage. Where the objectionable, intermittent system of supply exists, large storage cisterns are a necessity; but even with constant service, cisterns of smaller capacity are required. For instance, if nuisance is to be avoided, it is necessary that sufficient water should be stored to provide flushing water for water closets and similar fittings during the ever-recurring periods when the water is turned off for repairs to, or the making of, new service connection to the mains. Again, when a hot-water supply apparatus is fitted, its construction necessitates the provision of a cistern to supply it, because such an apparatus, as constructed in this country, cannot be safely or satisfactorily worked direct from the main pipe. Again, and especially in large establishments, the want of water for general purposes, even for the few hours required for ordinary tapping of the mains for fresh connections, would be a serious drawback, so that a cistern sufficiently large to carry over such a period, if not a necessity, is a convenience often provided.

Flushing Cisterns.—In all cisterns one rule should be inexorable—namely, that a cistern used for flushing water must never be used to supply water for other household purposes. According to this rule modern arrangements require that each water-closet, housemaids' or bedroom slop sink, and single urinal, or urinal range, must have a separate flushing cistern fixed

over it. For preventing waste of water these cisterns must be what are called waste-not cisterns, that is to say, constructed so that they will only discharge a measured quantity at a time; but for preventing nuisance, arising from insufficient flush, they should be so designed, that when once the flush is started, the full quantity will be discharged, whether the actuating handle is held open by the user during the whole period of the flushing discharge or no. There are many flushing cisterns in the market which do this, and these should always be insisted on. The reserve water for flushing is sometimes provided as part of these flushing cisterns, and sometimes by means of a separate store cistern, supplying all of the flushing cisterns. If the latter arrangement is adopted, the general store cistern, being in that way cut off by the flushing cistern from the fittings, may be used also for the general house supply; but it is better to have a separate cistern for this purpose. As hot water supply is often used for cooking and drinking purposes, it is, of course, necessary that the cistern supplying it should be as carefully preserved from pollution, as that for a general household supply.

Store Cisterns.—The following rules regarding these cisterns should always be attended to:—

Their position should be such as to provide ready access for inspection and cleansing, and while it is well that there should be light enough to ensure the cisterns and their surroundings being kept clean, they should always be covered-in sufficiently to prevent access of light and dust to the contained water, and also to prevent animals falling in, and so polluting the water. At the same time, ventilation by wire gauze-covered openings or the like, is necessary. The material should be such that it will not decay or communicate any dangerous or objectionable substance by solution in the water. Wood is objectionable for the first reason, and, in the case of certain waters, lead, copper or black iron for the second. In the

case of waters which do not readily dissolve it, lead is, however, a convenient and durable material, while copper can often be effectually protected by tinning, and black iron if painted *when new* with good bitumen paint, will be protected for a long time against the action of waters corrosive to uncoated iron. Galvanized iron is a good and cheap material for cisterns. Slate is also unobjectionable, provided the joints are made with cement, and not with red lead, as is often the case. Glazed earthenware cisterns have also been made, and this forms an ideal material for the purpose, but if made in one piece they are necessarily limited in size, and their great weight is an objection in many cases.

Over-flow Pipes.—In old houses the inspector will often find that the over-flow pipes are connected to some convenient water-closet soil pipe, waste pipe from baths or basins, or drain. This arrangement should be at once condemned, for in most cases, such a pipe simply forms a ventilator for the drains, discharging foul vapours immediately over the surface of the water in the cistern, and also, usually into the house. Modern requirements demand that all over-flows from cisterns must discharge into the open air, either over a sink or yard gully, or, better still, into the roof gutters or simply through an outer wall.

Cleansing Pipes.—It is very desirable that every cistern should be provided with a good-sized emptying pipe, to be used during the periodical cleaning of the cistern, (which should never be neglected), for the purpose of thoroughly flushing out the inevitable deposit and the dirty water, resulting from stirring it up in cleaning. The over-flow pipe can often be arranged to serve also as a cleansing pipe, but in such a case, it must be made to discharge in some place where the large quantity of dirty water resulting from cleaning, can be carried off without doing damage or causing offence. In such cases the arrangement adopted, is that called by plumbers the standing

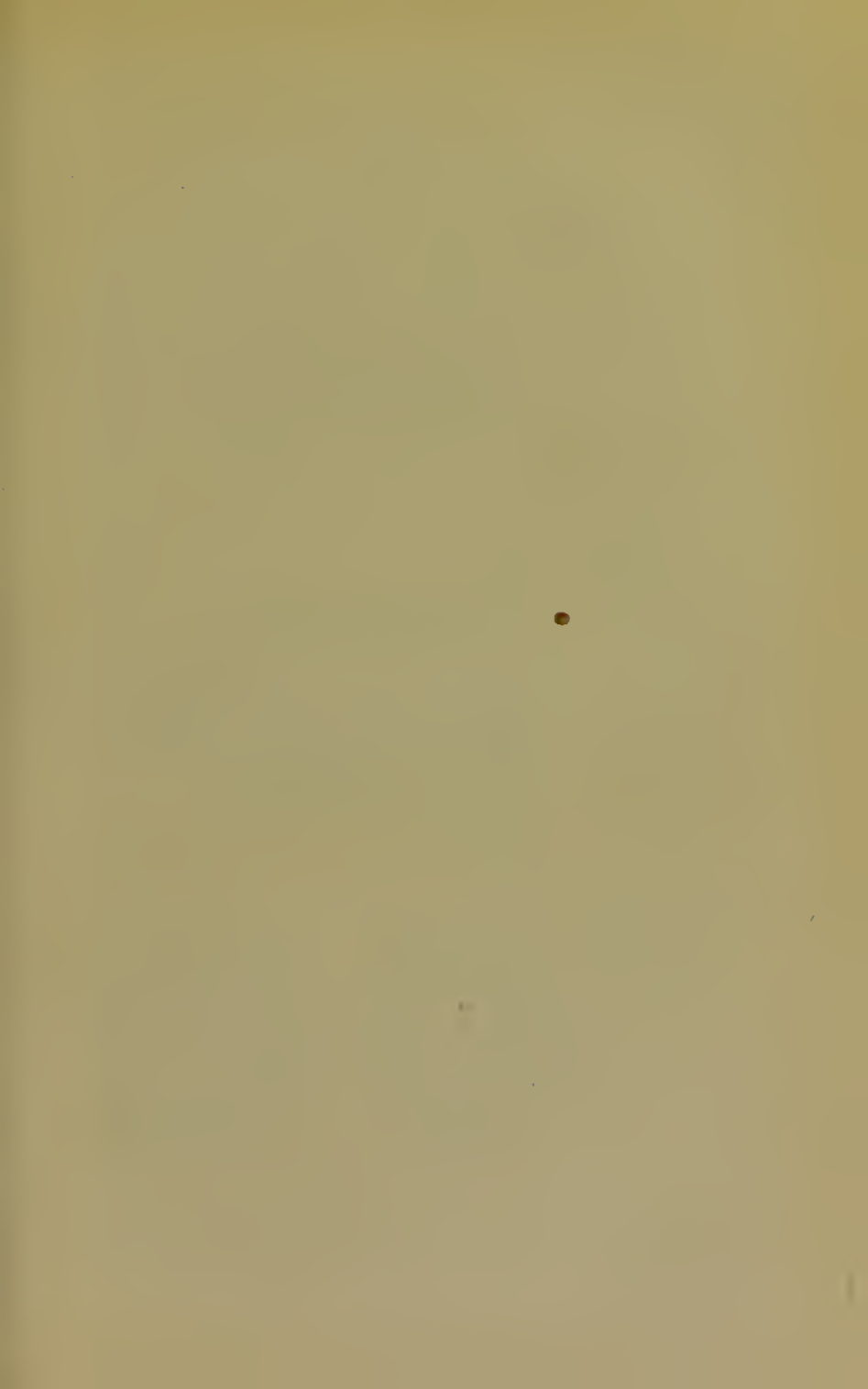
over-flow pipe and plug and washer. In this, the combined over-flow and cleansing pipe is led to the bottom of the cistern, and connected to a brass plug and washer, similar to those used in ordinary baths and basins, but of much larger size. The centre of the plug is bored out, and a pipe, the length of the intended water level in the cistern, is fixed, rising up from it, which forms what is called the standing over-flow, the over-flow taking place over the top edges of this pipe, and so into the pipe below the cistern. When required for cleansing, the standing overflow, with the plug attached, is lifted out, and this provides an opening at the bottom of the cistern, whereby it can be emptied and flushed out. . When a cleansing pipe is provided, it is desirable to fix the supply pipe from the cistern to the house fittings, a little above the level of the bottom of the cistern, so that it shall be above any deposit forming in the cistern ; but if the special cleansing pipe is omitted, the service must be fixed at the bottom, as the service pipe must also in such cases be the emptying pipe, although the arrangement is an undesirable one.

Basin and Bath Supplies.—In the older class of basin and bath fittings, an arrangement is sometimes met with, whereby the water supply is made to flow in, by way of the emptying grating in the bottom. This method is prohibited in all new fittings by the water supply authorities, because, by it, the water may run to waste without being noticed ; but, beyond that, it is highly objectionable from a sanitary point of view, because the water must necessarily be polluted in flowing through such a channel. All such fittings should have the water supply delivered over the surface of the highest possible water level in the bath or basin, and any other arrangement should be condemned.

Purification of Water.—The best classes of water require no purification before usage, but in many of the waters available for supply, some form of purifica

tion is desirable or necessary. In the case of public water supplies, the question of purification is one for the sanitary engineer; but in what may be called private, supplies the question becomes personal to each user, and it is in such cases mostly that the matter becomes of importance to the sanitary inspector. It is possible, by careful and proper treatment, to purify and render fit for usage, even waters which in their natural state are much polluted, and it is therefore necessary for the sanitary inspector to have knowledge of the methods whereby such results can be attained. The modern method of biological treatment has rendered it possible to purify water even when polluted with sewage matter, and as is now known these methods enter largely into the operations proceeding in many of the filtration methods now in use. The operations may be divided into sedimentation, filtration, and chemical treatment. Chemical treatment need hardly be considered in this work, as it requires an attention, and specialist knowledge for its working, not to be expected or attained by the general public, and is therefore not to be trusted to, in their hands. Sedimentation and filtration may be, however, rendered to a large extent an automatic action, requiring only periodical attention to the cleansing out of the apparatus, although even that periodical attention is too often omitted by the private user.

Sedimentation.—Sedimentation, as its name implies, is simply a provision whereby when sufficient time is given, still, or very slowly flowing water deposits its heavier suspended matter, together with certain other constituents. It is true that these matters can also be removed by filtration alone, but their effect is to clog up the filter more rapidly than otherwise would be the case, and it is therefore often desirable that sedimentation, to some extent at all events, should be a preliminary to filtration. All dams, tanks, and wells which are of sufficient capacity to prevent any great disturbance of their



contents by the current, caused by the water drawn off for use, act as sedimentation tanks, and hence the necessity for their periodical cleansing. When it is desired to construct a special sedimentation tank, as when the water is drawn from a creek or other source liable to be rendered muddy by floods, this can be done simply, by adopting the principle of what is known as the Dortmund precipitation tank. The diagram Fig 7 shows a section of this tank, which is used for the precipitation of sewage sludge, but the principle of which is equally applicable to the sedimentation of water. It will be observed that the tank is of considerable depth in proportion to its diameter. The liquid is delivered into the tank at the top of a vertical pipe, which passes down the centre nearly to the bottom. Here, by means of a spreader, the downward flow of the liquid through this pipe is arrested, and spread horizontally so as not to disturb the sediment already deposited. From this point it rises very slowly to the top, where it is drawn off. The large diameter of the tank in proportion to the pipe renders the upward flow exceedingly slow, so slow, in fact, that the deposit falls through the water with greater speed than the speed of the upward flow of the liquid, and is so deposited. It will be observed, that there is practically no head lost in the apparatus, that is to say, the outflow level is nearly the same as that of the inflow. Such a tank can, therefore, be provided, and sunk below a line of pipe, and, if the bottom is made conical, the deposit can be pumped out at intervals; or, if a fall of even eight to twelve inches below the line of flow can be obtained, it may often be made to discharge by gravitation. If placed above ground the whole arrangement can be constructed in galvanized iron, and will work efficiently.

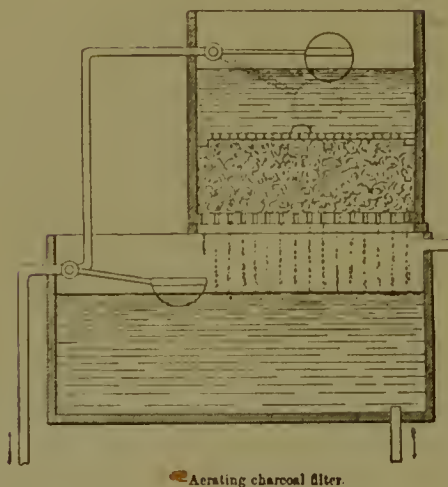
Filtration.—Filtration may be effected by straining alone, or by straining combined with the action of purifying organisms. The former is the method adopted in two of the most reliable and

efficient household filters in the market, namely, the "Pasteur Chamberlain" and the "Berkefeld," and the latter, in the ordinary sand filters which are almost universally used in water filtration on a large scale. These filters are usually about 4 feet to 5 feet deep, composed of an upper layer, 18 inches to 2 feet deep, of clean washed sand, and underneath from 2 feet to 3 feet of coarser material, and having open channels for collecting the water at the bottom, formed of bricks set without mortar, or open-jointed glazed earthenware pipes, etc. These filters are not effective when first brought into use, because it is necessary that a film, or matt, be established on the surface of the sand, and that the purifying organisms should multiply within the interstices of the filtering material. When this is fully accomplished the filter is at its best. The water must not pass through too rapidly, otherwise, time for the effective action of the organisms will not be afforded. The rate of filtration adopted in the most recent British practice is about 5 feet vertically per 24 hours. This means, that the water is allowed to sink through the filter at the rate of 5 feet in twenty-four hours, thus showing that each superficial foot of filter surface will purify five cubic feet, that is, $5 \times 6\frac{1}{4}$, or $32\frac{1}{2}$ gallons per day.

In some text-books it is stated that the water may be passed through at a much quicker speed than this, and in certain American examples much quicker filtration is adopted. Of course, the rate depends to some extent on the degree of purity of the water to be filtered, but even allowing for that, the rates common in some cases in America are excessive. At all events, the rate given above is a safe one to adopt. The film, or matt, which forms the straining part of the sand filter of course clogs up after a time, owing to the constant deposit on it of suspended impurities from the water, necessitating periodical cleansing of the surface. This is effected either by paring off a thin layer of the

AUTOMATIC AERATING HOUSEHOLD FILTER.

FIG. 8.



DESCRIPTION.—The lower tank is the clear water cistern ; the upper tank forms the filter. The water supply pipe passes up as shewn, discharging into the upper or filter tank. The ball valve in the lower tank cuts off the supply to the upper ball valve when that tank is full. The upper ball valve cuts off the supply to the filter, when the water level rises as shewn in drawing, until the water filters down into the lower tank, when the ball valve takes the position, shewn by dotted lines, so again admitting the water over the filtering material. When the lower tank is full its ball valve cuts off the water supply entirely, permitting the filtering material to drain dry and so become re-aerated.

sand (which is the method commonly adopted in public supplies), or by causing a strong current of previously filtered water to flow back through the filter. That is to say, the clean water is caused to enter the filter from the bottom, and so, flowing upwards through the sand with some velocity it lifts the deposited matter from the sand surface, and returns it to the sedimentation tank, when such is provided, or oftener allows it to run to waste. It is this straining part of the sand filter which renders the preliminary sedimentation desirable.

There is nothing which clogs up a sand filter more rapidly than the finely-divided clay, etc., and vegetable matters which come down with many creek waters, particularly when the flow is rapid; and the greater part of these can be got rid of, in a sedimentation tank, so greatly lengthening the intervals between the needful cleansing of the filter beds. The upward flow method of cleansing is most suitable for private use, as it can usually be simply actuated with the minimum of trouble to the user; and this is everything in such cases. The diagram Fig. 8 shows a very efficient and simple automatic and self-aerating filtering arrangement, as applied to an ordinary household cistern. Here the filter is placed over the cistern, although this is not absolutely necessary, provided the filter is placed sufficiently high, so that the water can flow into the cistern above its water level. Two ball valves are provided; the lower one, which regulates the supply to the upper one, is actuated by the level of the water in the filtered water cistern. The upper one, which regulates the supply to the filter, is actuated by the level of the water in the filter. When the water in the cistern is drawn off for use, the water level, of course, falls, and, the lower ball valve falling with it, is opened. The filter is usually empty when this happens, so the water flows through the opened upper ball valve on to the surface of the filtering material. As the water rises here, the upper ball

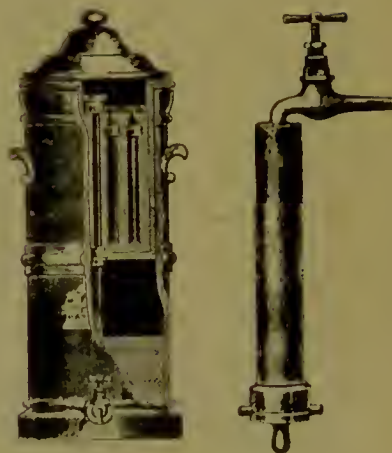
valve, rising with it, closes partly, so allowing the water to filter slowly through the cistern. When the latter fills up, the lower ball valve closes, so cutting off the supply to the upper ball valve, and to the filter. When this happens, the water remaining in the filter gradually drains off into the cistern, so leaving the filter empty till the next usage of water, and thus effecting the periodical aeration of the filtering material necessary for its continued efficiency. It will be seen, that an upward flow cleansing arrangement for the filter can easily be made, by providing it with a water-tight bottom, below the level of the perforated bottom shown, and leading the water by an open pipe to the cistern. This pipe can easily be so arranged that it can be connected to a small hand-pump, whereby the water can be pumped upwards through the filtering material, and the washings carried off to waste by means of an overflow pipe placed in the filter above the level of the ball valve cut off. A sedimentation tank of the type already described can also be attached, where deemed necessary, but its overflow must of course in this case be well above the level of the filter ball valve, and its inlet should be regulated by the level of the water in the cistern. This arrangement has been described in detail because it furnishes a very efficient and simple means of purifying a private supply.

Household Filters.—Household or domestic filters are very generally used, because of their cheapness and ease of application, but very great ignorance prevails as to their working and efficiency. As already pointed out, all filters require periodical cleansing, and if this is neglected the water which passes through will ultimately be more impure than that entering. Very many of the filters in the market do not clog up when dirty, but continue to pass water through for an indefinite period, and, as the so-called filtered water becomes more and more

THE PASTEUR CHAMBERLAIN FILTER.

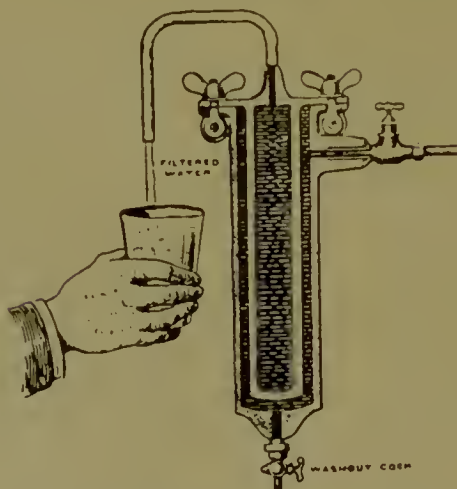
FIG. 9.

DESCRIPTION. — The drawings show a single candle pressure filter attached to the water supply tap, and also an ordinary household filter with part of the side removed, showing the arrangement of the group of filtering elements or candles, and the chamber for filtered water.



THE BERKFELD FILTER.

FIG. 10.



DESCRIPTION. — This Filter is on practically the same principle as the Pasteur-Chamberlain, except that the material of the filtering candle is different. The rate of filtration is more rapid.

impure as time goes on, these are very dangerous for the ordinary, careless private usage.

The safest filter in such cases is one which clogs up, and so ceases to pass water when it becomes dirty, thus compelling the user to cleanse it in order to obtain water at all. This, as pointed out, is a quality possessed by the ordinary sand filter, and it is also the case with both the Pasteur Chamberlain and the Berkefeld. The illustrations, Figs. 9 and 10, show sections of these filters. Both are constructed on the same principle, but the material used for the straining medium is different. In the former, it is fine unglazed porcelain; in the latter it is baked silica. The medium is formed into a tube, closed at both ends, and the water is made to pass from the outside inwards, and passes from the inside to the draw-off pipe. The rate of filtration is slow in both cases, but the water is thoroughly purified. These filters can either be connected to the water supply under pressure, or can be placed in an ordinary household filter, but in the latter case, it is necessary to use a group, or battery of the filtering element, or candles, as they are technically called, in order to obtain a sufficient supply. Each Pasteur candle can supply about five gallons of water per day, when under the ordinary main pressure, which is enough to provide cooking and drinking water for about five persons. These elements are readily accessible for cleansing, and this is effected by scrubbing, and additional security may be attained by subsequently boiling them.

There are other materials used for filtering media, which are efficient when periodically cleaned, such as spongy iron, magnetic carbide of iron, and polarite; but these do not possess the quality of clogging up when dirty, so that that safeguard is lost in their use.

In concluding this part of the general subject, the absolute necessity of periodical cleansing in every filter cannot be too strongly urged, and it of course

follows that any filter wherein the filtering material is so sealed up as to be inaccessible, should be at once condemned ; and further, it may be added, that any organic substances capable of decay, such as sponge, or cotton wool, should find no place in any filter, as sooner or later they must decay, and so pollute the water.

CHAPTER V.

PARASITES.

Specific diseases are caused by pathogenic micro-organisms belonging rather to the vegetable than to the animal kingdom. In addition to these diseases the human body is liable to be invaded by a number of parasitic organisms, which are nourished wholly or partially at the expense of other living organisms. Kossman divides parasites into two great classes :—

1. Vegetable forms, or those without independent digestive organs. 2. Those with independent digestive systems.

The parasites of man cover a wide range in the animal and vegetable world, and include—Blastomycetes, Hyphomycetes, Schizomycetes, Protozoa, Insecta, Arachnida Suctoria, Nematoda, Cestoda, and Trematoda.

Blastomycetes or Yeasts.—Are of interest in that a species of *Torula* is connected with a well-defined disease called thrush in infants.

Hyphomycetes or Moulds.—Of these *oidium lactis* is found in sour milk, bread, paste, potato, and gelatin. Ringworm also belongs to this group, and *Aspergillus* is found in lungs and ear of man. *Botrytis Bassiana* is a fatal disease among silkworms, and is described as a cause of a disease known in India as “madura foot.” Actinomycosis or rayfungus attacks cattle, especially in the jaws, and also man, in whom it may invade the alimentary tract, the lungs, the subcutaneous and intermuscular tissue. The natural habitat of this fungus is on the ccrealia (especially barley) and through and from these enters the animal body through wounds, abrasions, &c.

Protozoa.—Various observers have found that these lower forms of animal life perform the function of a parasite to man. The micro-organism found in cases of dysentery, *Amoeba dysenteriae*, belongs to this order, as also do certain coccidia. The contagious epithelioma of poultry and pigeons is occasioned by a similar organism, whilst the *Molluscum contagiosum* of man is due to the same or similar parasites (Neisser).

Insecta.—*Culex auxifer*, or mosquito, is of importance as intermediate bearer of human filariae. *Pulex penetrans*, jigger or chigoe lives in the ground in some parts of Africa, and bores its way beneath the skin causing much inflammation and discomfort. Of the pediculi, or lice, five distinct kinds are recognised as human parasites.

Arachnida.—The chief human parasite of this class is the common itch insect *Acarus scabiei*.

Of the *Suctorio* the leech is the sole one which attacks man, and is generally introduced by drinking water through which the animal has been introduced into the larynx and air passages, and fauces

Those parasites called *Nematoda* are probably the best known of all parasites of man. The common thread-worm which infests the large intestine belongs to this class, and they are probably taken into the system through the ingestion of improperly cooked or raw vegetables and water. *Ascaris lumbricoides* or round worm, six inches in length, pinkish in colour, and tapering at each end, is another of this order, and it infests the small bowel. Pigs are sometimes infested with this worm. The *whip worm* commonly affects man in the tropics, and is taken into the system through drinking water. Years ago, when James Paget was a student at St. Bartholomew's Hospital, he noticed that certain ovoid calcareous-like bodies blunted the dissecting scalpels, and through his industry and the use of the microscope, which in those days was difficult to procure, it was revealed to

man that these ovoid bodies contained a small worm $\frac{1}{16}$ of an inch in length. This worm *Trichina Spiralis*, the cause of trichinosis in man, attacks pigs and infests their muscles and fat. They develop and breed rapidly, and by burrowing through the intestinal walls, are able to find their way into all parts of the body of the individual who consumes the infected pork. Trichinosis causes nausea, vomiting, abdominal pain, irregularity of the bowels, prostration, rapid pulse and elevation of temperature. It may prove fatal, through enteritis, peritonitis, pneumonia, or exhaustion, at any time from the first to the sixth week. At the onset the muscles become painful, tender, swollen, and stiff. The limbs are flexed and motionless; the voice is often hoarse and aphonic, and there may be general oedema.

Filaria Medinensis, or guinea worm is endemic in parts of India, Persia, Arabia, Egypt, and other tropical countries. It attacks man and other animals, and varies in length from one to twelve feet. It usually gains access to the body of man through the skin, boring its way into the tissues. They are aquatic in their life, and commence their cycle of existence in the crustacea. They usually attack the feet, legs, and back of man. In Australia, as well as in other countries, the *dochmius duodenalis*, the eggs of which undergo development in damp soils, attacks those who handle earth, especially men engaged in tunnelling and brickmakers. *Filaria sanguinis*, found in the blood of man, is a hair-like parasite which abounds in the blood of the affected persons, and may be present during the day to disappear during the night, and *vice versa*. It is usually associated with such diseases as chyluria and elephantiasis. The order *Cestoda* includes the great group of tapeworms. *Tænia solium* rarely exceeds 3·5 metres in length, and has 850 segments. According to Notter and Firth, it is comparatively rare, and attains a length of from seven to ten feet. The head is about the size of that of a pin, has a

spherical shape, and bears four suckorial plates or discs with a double circle of hooklets. Its cysticereus or bladder worm affects the pig and attacks its muscles, causing measly pork. It usually reaches man through the digestive track, either by water, food, or by the hand. *Tania mediocanellata* is the only cystic tapeworm with an unarmed head which occurs in man. It is the longest of the tapeworms, and is composed of 1000 to 1300 segments. The eggs are commonly expelled with the dejecta of the host, and, if they gain access to the alimentary canal of the ox, there develop an embryo which passes into the voluntary muscles of the animal and forms the beef measles, or *Cysticercus bovis*. In the dog and the canine species generally there frequently occurs a small tapeworm about 5 millimetres long. When the eggs of *tania echinococcus* escape, the contained embryo, if it finds its way into the body of man, assumes a larval stage and burrows into various parts of the body, chiefly the liver. Here the cysticercus increases indefinitely and becomes the *hydatid* disease of man, forming within itself secondary cysts, called daughter cysts. *Bothriocephalus latus* is a short-jointed broad tapeworm, about twenty-seven feet long and is usually found in Russia, Poland, Sweden, and Switzerland. Certain kinds of freshwater fish act as the intermediate host of this worm. To the order of *Trematoda* belong the flukes and also *Bilharzia hæmatobia*, which are found in the portal vein and give rise to violent hæmaturia.

CHAPTER VI.

INFECTIOUS DISEASES.

The principal methods of infection are :—

Pulmonary infection, the bacilli or spores being inspired.

Intestinal infection, the organisms being swallowed with food, water, or dust.

Inoculation through a wounded or unwounded surface of the skin or mucous membrane.

Infection by contagion, fomites, etc., in which the manner of entrance of the virus into the body is not precisely understood.

The occurrence of an attack of one of the infective diseases implies the action of microbial life upon the affected person, and as such diseases arise from specific excitants, they are either reproduced upon or in the bodies of the sufferers, or the poison is carried in the secretions. The virus of any one disease may be communicated either by the specific contagia upon which it depends being evolved from one person, and reproduced in the contaminated organism, or by being carried in the secretions, and undergoing development outside the body. "The question, therefore, whether diseases do or do not descend in a continuous series from antecedent cases is one which must be worked out separately, as regards each disease, by a study both of the epidemiological behaviour of different diseases, and the life history of particular microphytes upon which such diseases depend." The number of specific or zymotic diseases is steadily increasing, owing to improved methods of observation, and many attacks of disease in man are due to micro-organisms which, although not developed *de novo*, are really derived from a particular species

that has not for generations found a habitat in man or other animals. As regards the recipient, the mode of infection is varied, for through aerial convection, many diseases are carried from one zone to another zone, where the active principle may be taken into the system by the fauces or the lungs, by food and drink. Infectious matter is not immediately altered or destroyed, and its possibility for harm is unlimited; for in typhoid fever, as the faeces dry, its particles may be carried either into drinking water or the atmosphere, and happy is the man who neither drinks the one nor breathes the other when so contaminated. Infection, then, may be, personal, through a specific poison being transmitted from one person to another; it may arise *de novo*, and occasionally springs upon us without apparent specific cause in localities which have for years been free of them. The origin of infectious disease is hidden in the night of time, and the supposed logical necessity of an immediately antecedent human case is now lost, since we have become better acquainted with the mode of propagation of the actual living *materies morbi*, through experimental culture of it in dead media for indefinite periods. It is a matter of common knowledge that variations of severity and type are to be observed between different epidemics. These variations are possibly due to differences in the dose of virus, and differences due to variations of pathogenic power on the part of different species of micro-organisms. It is quite possible that the pathogenic properties of some microbes are acquired by a process of adaptation to environment, and during the transition from a purely saprophytic life to that of a parasitism. An epidemic of infective disease signifies a tendency on the part of the disease to spread over a large area of the earth's surface, regardless of local circumstances. The term "endemic" means that the disease may remain among the inhabitants of any area, where it is influenced by local conditions. Ransome and Whitelegge state that fatal infective

diseases "observe definite periodic times or cycles—that is, a succession of waves, the periods covered by the waves being different for different diseases. These waves are essentially of two kinds—the accidental and the fundamental. The former is a wave of mere prevalence, and probably but a reflex of changes in the environment. The true or fundamental cycle or wave is characterised by an increase of both prevalence and severity, and often extends over a considerable number of years. Though possibly not altogether independent of changes in environment, the true wave of periodicity of the infective diseases is more probably associated with microphytic evolutionary processes." Disease germs act in remarkably different styles in different animals, and the susceptibility of any animal to disease varies in degree. Some individuals appear by nature to be almost immune against attacks of disease. One of the peculiar characteristics of specific disease is that one attack frequently protects or gives immunity to the sufferer from further attacks. The duration of the period of this protection varies, and may extend only through a season, through a whole lifetime, or may be transmitted from the parent to the child. The cause of this protection or immunity is difficult to explain. An organism which invariably causes fatal disease in one animal, may either produce a mere local dyscrasia of no moment, or have no effect whatever on another animal. Therefore some animals are immune, while others are susceptible. The intensity of disease is therefore subject to variation, and although attacks of certain diseases—smallpox, measles, mumps, whooping-cough, scarlet fever—protect the person attacked against further attacks during life; still, on the other hand, such diseases as influenza, diphtheria, pneumonia, malaria, confer susceptibility to further attacks, and there may even be a distinct predisposition to attack by other diseases. Diphtheria and scarlet fever mutually predispose to one another.

It may be that the blood undergoing changes during an attack of disease is so acted upon that it never again affords the conditions necessary for the development of such a disease, and immunity is thus acquired. A toxic disease, such as tetanus or diphtheria, is due to pathogenic bacteria, which produce the ill-effects by the poisons they develop. It has been found that the blood of various animals possesses germicidal powers, and that if certain animals are rendered immune to attacks of disease, the serum of their blood possesses the power to render another animal able to resist the action of the toxalbumens produced by the disease-exciting organisms. Thus the body becomes armed against the growth of a specified organism, or the formation of its metabolic product, by putting into it, ready made, those products that would be produced naturally in convalescence, and would, by their action, bring the disease to a successful termination. The cells and tissues may also become so modified during an attack as to be able to resist further invasions of the same microbe, and to inhibit its growth. "*Acquired immunity, therefore, is a capacity to prevent the growth of disease organisms, of which the pathogenic action may lie in their intercellular tissue, or their metabolic products, or to neutralise the toxic action of such products.*" Between the time of infection and the appearance of the first symptoms of infective disease there intervenes a latent period called incubation. The duration of this period is fairly constant for each disease, and little is accurately known of the changes which occur beyond the fact that the poison is multiplying in some part of the system. According to Squire, diseases with similar incubation may run their course concurrently in the same individual independently, without interfering with each other. The course of an infective disease is like that of a plant, and has a period of development, a period of greatest vigour, and a period of death. The time of development is the period of

incubation, which ranges from a few hours to weeks, and even years.

Disease.	Period of Incubation.	Duration of Infectivity.
Chicken Pox ...	10 to 14 days	3 weeks
Cholera	1 to 5 „	3 „
Diphtheria	1 to 8 „	6 „
Diarrhœa	1 to 4 „	1 to 2 „
Typhoid Fever ..	8 to 14 „	6 „
Erysipelas	1 to 5 „	1 „
Influenza	1 to 4 „	3 „
Measles	8 to 20 „	4 „
German Measles ...	6 to 14 „	3 „
Mumps	14 to 22 „	3 „
Scarlet Fever ...	1 to 6 „	6 to 8 „
Small Pox	12 „	6 „
Tuberculosis ...	unknown	During the whole disease
Typhus Fever ...	6 to 14 days	4 weeks
Whooping Cough ...	4 to 14 „	8 „
Plague	—	—

Anthrax.—A fatal, acute disease; appears with unusual frequency in certain districts, and is especially dangerous to cattle. The period of incubation varies from two to twelve days, and the disease usually affects man either as an external malignant pustule, or it produces symptoms of internal poisoning. The usual mode of infection is by inoculation, and is most frequent among those engaged in handling raw hides. It may be caused through the spores being swallowed in the form of dust.

In *Cerebro Spinal Fever*, the contagious principle is given off by the sick, and undergoes an intermediate stage of development in another animal before it can infect a human being. This disease has co-existed with an epizootic of the same nature among pigs and dogs. It is prevented by free ventilation and good food.

Chicken-pox has a characteristic vesicular eruption, which runs a similar course to that of small-pox, but the mortality is practically nothing.

Cholera -The *Spirillum Cholerae Asiaticae*, the organism producing true Asiatic Cholera, is generally known as Koch's comma bacillus. This disease is particularly endemic in India, but has been known to spread to other countries. The mortality is enormous, and the progress of the disease is influenced by climate, season, temperature, race, sex, and age. It spreads most rapidly when the earth temperature is high, and the ground-water is low, but rainfall has a marked effect upon it, epidemics occurring during and after rain. It occurs with greater severity among negroes than Europeans, and the mortality is greater among males at the extremes of life. It is transmitted by means of water (as at Hamburg), milk, uncooked vegetables; and the infection is confined to bowel and stomach discharges. General sanitary defects are conducive to its prevalence, especially by inducing a lowered standard of health. In fact, in the words of Sir John Simon—"The diffusion of cholera among us depends upon the numberless filthy facilities which are allowed to exist, and specially in our larger towns, for fouling of earth, air, and water, and thus secondarily for the infection of man, with whatever contagium may be contained in the miscellaneous outflowings of the population. Excrement sodden earth, excrement reeking air, excrement tainted water, these are for us the causes of cholera." The microbe or bacillus of cholera is readily capable of a saprophytic existence, and thus if cholera stools are thrown out on to the rubbish heap without being properly disinfected the organism might live in such a position for a considerable length of time, and perhaps by the action of rain find its way into any well near by, which has its supply from the surface water. The dangers, therefore, which have to be guarded against as favouring the spread of cholera

infection are particularly two, viz., danger through impurity of water supply, and danger of breathing air which is foul with effluvia. *Dengue*, a specific febrile disease characterised by severe articular and muscular pain, and often by a cutaneous eruption, is a disease peculiar to warm climates, and occurs in Australia. In the intensity of its epidemic manifestations it resembles influenza, as it spreads mainly by personal contact. It is influenced by heat, but not by the geological characters of the soil, and occurs chiefly in towns, especially in low-lying, filthy, overcrowded quarters. The infection may be assumed to be parasitic, and to be given off usually by the breath, and possibly by the secretions and cutaneous emanations. *Diarrhœa* is simply a physiological process, and merely symptomatic of either the normal reaction of a healthy bowel against irritating contents, or of some morbid internal condition. The spread of diarrhœa is influenced very greatly by an insufficient water supply, through the lowering of the state of health. When diarrhœa becomes endemic in any community it is almost always owing to impure air, impure water, or bad food. Climate and season have always exercised a great power over different diseases, and often supply favourable conditions of propagation, for when the temperature is high and the atmosphere dry the germs of disease flourish rapidly because their vitality is promoted. On the other hand, excessive humidity of the atmosphere, during the persistence of high temperatures, favours putrefaction, and, while a high temperature persists, it matters little whether the atmosphere is excessively humid or excessively dry, for the danger of disease originating is about the same. According to Ballard, "the essential cause of diarrhœa resides ordinarily in the superficial layers of the soil, where it is intimately associated with the life processes of some micro-organism not yet isolated, detected, or captured." Tomkins, of Leicester, is also of opinion that "the cause of diarrhœa is a soil-bred organism," and that organic pollution of the soil renders

it distinctly favourable to a high mortality from diarrhoea, especially through those made soils where liquid filth is allowed to pollute the earth beneath. No age is exempt from attack, but the liability seems to be slightly greater during the second year of life. Tomkins states that "infants and young children form only a small proportion of those attacked, although they furnish nearly the whole of the deaths." According to Tomkins, "the air is peculiarly rich in microbial life during diarrhoea epidemics; and among these prevalent micro-organisms are certain small bacilli, cultivations of which cause diarrhoea when swallowed." Loose porous soil is most conducive to the mortality from diarrhoea, particularly if coupled with organic fouling of the earth. The mortality from diarrhoea is usually great when the temperature of the air is high, but this influence, although great, usually exerts itself in an indirect manner. Springthorpe, of Melbourne, finds that diarrhoea becomes epidemic when the mean temperature has reached an elevation of 60° F, but in Sydney it is found that this necessary elevation is at least, 65° F. Ballard has found that when the earth temperature, at four feet from the surface, reaches 56° F., no matter what the mean atmosphere temperature may be, there is a rise in the prevalence of diarrhoea. Dr. Mailler Kendall finds from his own observations that the summer rise of diarrhoea occurs when the temperature of four feet earth thermometer reaches 60° F. The maximum mortality, therefore, and decline in the diarrhoea rate, coincide with the mean weekly maximum and decline of the temperature recorded by the four-feet earth thermometer. Rainfall exerts little influence, and excessive dryness or complete wetness of the soil both appear to be unfavourable to diarrhoea. That degree of habitual dampness, which, while being marked, is not sufficient to preclude the free admission of air between the constituent physical elements of the soil, is specially favourable to diarrhoea.

Such a degree of dampness obtains when, in the season of diarrhœa, the subsoil water stands sufficiently near the surface to maintain by capillary attraction, the dampness brought about by previously greater nearness of the water to the surface. Wind lessens the mortality, but calm, stagnant days promote it. The prevalence and death-rate of diarrhœa are notoriously greatest among the very poor, and they are associated with want of cleanliness. Foul air from sewers and cesspools, and accumulations of filth favour diarrhœa mortality, and as such also occur in made soil, and many observers are of opinion that diarrhœa is a disease of the soil, measures must be taken to preserve the soil itself free from germs of an evil nature. It is now an assured fact that epidemic diarrhœa is "caused by the pollution of air, water and food, by the products of the decomposition of organic matter during very hot weather." An important point is the vulnerability of the individual, and the general state of the individual's health, for a low state of health renders the individual more prone to contract disease, more especially as unwholesome gases are given off from a filth sodden soil in which anaerobic organisms are found and putrefaction is going on.

Professor Klein has recently discovered that there is a bacillus, *Enteriditis sporogenes*, contained in horse dung, which causes diarrhœa. The mud of wood-paved streets is chiefly composed of horse dung, and when this becomes dry, it is blown about the streets, to be inhaled by anyone, to the detriment of health, for the inhalation of finely-pulverised horse dung cannot be a useful application to the respiratory mucous membranes. Such a cause can only be met by efficient municipal control, and a cessation of that abominable and insanitary practice of sending out dust carts to take away house refuse and horse droppings at all times of the day.

Dr. Newsholme maintains that "diarrhœa is essentially a filth disease, due to a micro-organism

which flourishes in a polluted surface soil ; and while every effect has an ancestry of causes, and every cause a posterity of effects, the unconditional cause of diarrhœa is a micro-organism, possibly the bacillus, *Enteriditis sporogenes* of Klein." It is in connection with the maintenance of the purity of the soil, and its habitual dampness as a factor of diarrhœa, that the laying of sewers plays so important a part. The laying of deep sewers assists in preserving the purity of the soil, and brings about a drying of the soil, which affects the variation of the earth temperature. Before the laying of sewers in the metropolis of Sydney, N.S.W., the rate of mortality from diarrhœa per 10,000 of the population was very high ; but since the laying of sewers, it has greatly decreased.

	Under 5 years.	5 years, under 10 years.	All ages.
Before laying of sewers ...	7·5	1·9	10·9
Since laying of sewers ...	1·0	·5	2·9

Before the laying of sewers in the city of Sydney the mortality from this disease reached 1·09, but it has now fallen to 1·8. This sanitary good fortune was also well marked in the suburbs, and the mortality from diarrhœa in all sewered districts has fallen by more than $\frac{1}{2}$, and in some places is less than one-third of its former rate.

Diphtheria is one of those diseases in which a distinct increase (which cannot be attributed entirely to improved diagnosis) has taken place in the past few years. Its tendency to reappear at intervals in particular districts would point to the specific organism having either a saprophytic tendency, or to its retaining its vitality in dust, and thus rendering the site of previous cases more or less permanently infective. The history of this affection indicates a tendency to cyclical epidemicity, though the cycles "have extended over periods of various length." No

climate gives immunity, but the affection is supposed to have greater incidence in cold and temperate climates. This toxic disease, which creeps slowly from place to place, shows a great predisposition to attack children between the ages of three and 12 years, and may exist in any place for months or years before it "takes root and begins actively to propagate itself." A filth disease, with a specific organism of a saprophytic nature, it favours damp soils, but it is difficult to regard the influence of soil states as etiological factors in this disease, although the micro-organisms may lie for an indefinite period dormant in the soil, and can regain their full energy as soon as the environment becomes favourable. The peculiarity of its distribution suggests, says Longstaff, "that the cause is not to be sought for in any of the higher developments of civilisation, such as sewers, but is to be looked for rather in some condition associated with a primitive form of life." Although the bacillus of Diphtheria has never been found in sewer air, the emanations of foul drains can induce an adynamic state of health, which might bring about a physical change in the system, so as to increase its susceptibility either through the simple vulnerability of the respiratory mucous membranes by which the infection enters, or by lessening the refractoriness of the whole system to infection. Faulty sanitary conditions may assist in the spread of this disease by preparing the throat for the bacillus, and may in this way apparently give rise to cases which would never have arisen had it not been for the existence of such conditions; but the removal of faulty sanitary circumstances has not always been followed by a diminution of disease, and Sir Richard Thorne has stated: "When in such outbreaks of Diphtheria as I have investigated, some obvious defect leading to the pollution of respired air by sewer or drain emanations, was regarded as the cause of the disease. I have found in almost every instance it was not only impossible to eliminate other

and better sources of infection, but also that some other alternative sources were generally found to have had obvious causal relation to the disease." He further states "that apart from age and susceptibility, school influence, so-called, tends to foster, diffuse, and enhance the potency of diphtheria, and this, in part at least, by the aggregation of children suffering from that 'sore throat,' which commonly is prevalent antecedent to, and concurrently with, diphtheria." This connection with school attendance is shown by what is known as the *holiday drop*, or cessation of the disease during certain periods of the year, and there is no doubt but that school attendance brings together those members of the community who are by reason of age most susceptible to the disease, into close contact and exceptionally close relationship to each other for many hours of the day. Such protracted close contact of children in schools, even if the ventilation is perfect, affords greater facilities for infection than would occur under home conditions, or during the hours of play in the open air. Diphtheria is an air-borne disease, whose bacillus is capable of a lengthened survival outside the body, particularly when surrounded by dust, and can quite possibly originate from the filthy dust-bin or municipal tip, which sends forth currents of air-sewage into healthy zones, and spreads infection from person to person by aërial convection. Cats suffer from a disease akin to diphtheria, and Klein says that milk, apart from human infection, may be infected with this disease by the cow herself. Beyond the scope of the direct action of a sewerage system, still through drying of the soil, lowering the height of the subsoil water, and improving the air, sanitary improvements act upon this disease, and antitoxin can never take the place of improved sanitary conditions in doing away with the breeding-places of the diphtheria bacillus outside the human body. Since the installation of the sewerage system in the metropolis of Sydney, the

mortality from this disease has fallen from 5·2 to ·3 per 10,000 of the population.

Dysentery.—A disease of hot climates, is endemic as we approach the equator. It is a seasonal disease, and attains its maximum in the summer or autumn. It is met with in dry and marshy places, and has a preference for damp and water-logged soils. Its outbreaks are, without doubt, attributable to pollution, and also to a faulty dietary and deficient nourishment. Foul water, polluted with faecal impurities, is the means by which the specific cause of dysentery is introduced into the system, and it is highly probable that this specific cause is often introduced into the system without giving rise to the disease. It is prevented by carrying out true sanitary law.

Typhoid Fever.—This disease can be traced back to the time when Henry, Prince of Wales, suffered from hemitræteus, but it was not until 1850 that Jenner was able clearly to demonstrate its differentiation from typhus fever.

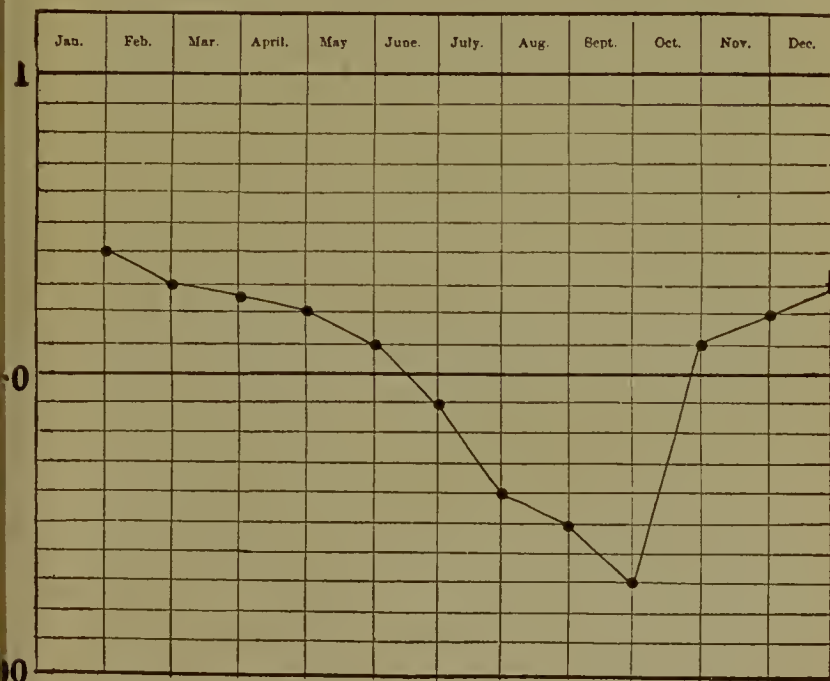
This disease, owing to the seeming impotence of medicine to effect a remedy, has become one of national importance, and a grave question to all deep-thinking politicians. Weather has no clear relation to the prevalence of this disease, except in so far that meteorological conditions may act by modifying the moisture and temperature of the soil, and that rain may increase or diminish the chance of an outbreak, according to the previous condition of the ground.

Sir Charles Cameron is of opinion that a high rainfall causes a diminution of typhoid fever, and that although there are many factors affecting the disease, still it is probable that cold wet years lessen, and hot dry years increase the disease. Dr. David Hardie, of Brisbane, is inclined to believe that a comparatively high temperature and continued dry weather during the winter and spring months, are

almost certainly followed, other things being equal, by an increased number of deaths in the following summer, and that during a rainy season comparatively few cases are met with. In our metropolis of Sydney, the greatest incidence of typhoid fever has rarely followed the sequence noticed by Dr. Hardie—in fact there has not been any constant relation between the rainfall and the prevalence of this disease. There are so many other more definite causes to be considered, that the influence of meteorological conditions cannot be very great, although it is quite possible that the combination of excessive heat with scanty rainfall may have some influence, or it may be that since rain increases the amount of atmospheric moisture, it thus assists the devitalising influences of a tropical climate by increasing putrefactive tendencies; for it is well known that in tropical climates the temperature and humidity of the air are highly favourable to putrefactive change, and tend to intensify those pollutions of air and water which are so inimical to health in all climates.

High or low temperature of the air in itself is said to have no clear relation to the prevalence of typhoid fever, except so far as it tends to modify the temperature of the soil, for as solar heat is the source of all energy, so it exercises supreme control over climatic conditions. Dr. David Hardie is of opinion that “the prevalence of typhoid fever in Australia has been distinctly shewn to be intimately associated with the atmospheric conditions that obtain, not only at the time of its occurrence, but for many months previous.” He remarks that “a person whose backyard is untidy or uncleanly in summer does not usually shew more intelligent interest in matters pertaining to sanitation during the winter months, or, if so, the difference is not sufficient to account for the prevalence of typhoid fever at one time more than another.” Transportable miasmata are originally due to internal local conditions of soil and water; and Hirsch has pointed out the devitalising

SEASONAL RHYTHM OF TYPHOID MORTALITY.



This table is the mean seasonal rhythm for seven years, and is calculated for each 10,000 of the population.

influence of a tropical climate, and Wilson has attributed to a prolonged residence in it, shortening of the duration of life and weakening of the constitution.

There is no evidence to show that race of itself has any great influence over liability to be attacked by typhoid fever, and much the same conclusion can be drawn as to sex, but the influence of age is very marked in this disease, and the greater number of cases occur between fifteen and twenty years of age, and become fewer and fewer as age passes thirty years, although here, in Australia, it occurs frequently among persons of mature years, even up to such an age as seventy-eight and seventy-nine years.

The incidence of typhoid fever is directly influenced by season, the greater number of cases occurring during the summer and autumn. Little is known of the exact climatic conditions upon which this seasonal rhythm depends, but there is without doubt some relation to heat and cold. In Sydney, New South Wales, the highest mortality usually occurs during the first four months of the year—January, February, March, and April—these months forming the hottest third of the year. Up to the present time this disease is not so prevalent during the winter months, and is almost absent till the end of the spring, when it begins to increase during October, and gradually becomes more evident during the months of November and December.

“Any epidemic of typhoid fever,” says Dr. Wilson, “in a sewered town, points to imperfect ventilation, faulty construction of drains or sewers, deficient flushing, to contamination of the water supply, or to polluted milk.” In unsewered districts it points to some defect in the removal of human refuse, waste waters, filthy privies, and cesspools where the specific contagion may be propagated. There may be doubt as to the microbial relations of typhoid fever, but no one doubts that it is a filth disease, and that during epidemics the greatest incidence of the attack is

always heaviest upon houses or districts where drainage defects exist. According to Dr. Haviland, "typhoid fever has no reason for existing at all," but Dr. John Drysdale remarks that "although the area of its operations may be circumscribed, still it can never be hoped that good food, drainage or ventilation will extinguish it altogether, as long as man is a social animal."

According to Wynter Blyth, the most reasonable theory is, that "the cause of typhoid fever is a vegetable parasite capable of having an independent existence, of propagating its kind, and completing its cycle of existence quite independent of the body. Hence the impossibility of tracing typhoid from one person to another, hence its endemic prevalence in certain parts, and hence the mysterious isolated outbreaks which sometimes occur." This statement is open to some comment, and it has been maintained that typhoid fever is always the result of infection from an antecedent case of the disease. Its incidence is heaviest where drainage defects exist; although it is very difficult to dissociate their influence from that of co-existent hygienic defects, such as a want of personal cleanliness, impurity of soil, and impurity of water. The contagion is usually carried by sewage, but direct contagion is not unknown. The virus may be transported by air, sewer gas, and polluted water—a single enteric stool entering a source of water supply being sufficient to infect a whole town. One of the most striking instances of recent date of the danger due to polluted water supply is the disastrous epidemic which lately has devastated the population of Maidstone, in England. This epidemic was distinctly traced to contamination of the water supply through a party of hop-pickers pitching their camp close to the springs forming the source of the water supply, and, as enteric fever broke out in this camp, so the water supply became contaminated.

The *contagium vivum* of typhoid fever has generally been admitted to leave the body by means of the stools; therefore, the prevention of the infection is not

the purification of sewage, but the destruction of the germs before they have escaped from the sick room. The infection of typhoid fever may be communicated directly from one individual to another, or by means of some vehicle such as food, water, or milk containing the microbe of disease. Dr. Priestly considers that in all probability typhoid fever spreads by actual contact oftener than is generally supposed, and that as cases frequently remain unrecognised for long periods, "such cases are mainly responsible for spreading the disease."

If typhoid fever is caused by a specific organism of a pathogenic nature, we must look for the cause of every case in the specific contagion given off by a previous case, and as the virus appears to be air-borne only for very short distances, its chief means of propagation must either be through the organism becoming endemic on the soil in close proximity to the patient's abode, or through its finding its way into milk or water, or adhering to articles of food, such as vegetables or shell-fish.

The subsoil, beneath a house, may, if dry, contain in its pores or air spaces a vast amount of air, or if wet, a considerable quantity of water; consequently there is a great need for taking precaution so that the subsoil shall not become contaminated with house refuse or human excreta, for typhoid fever is especially spread by means of excremental matters, and is very prevalent upon pervious soils. Pettenköfer says that the conditions requisite for an outbreak of typhoid fever are—a rapid fall, after a rise of the ground water—pollution of the soil by animal impurities—a certain earth temperature, and the presence of a specific organism. The best pabulum for the supposed microbe is contained by a warm, moist, well aerated soil. Porous soils (sand or gravel) with a low level of ground water, are the warmest, and, in the main, the healthiest soils, but they are most liable to organic pollution, and Sir Charles Cameron points out that, "It is in the low-lying districts and on the gravels where there is most typhoid fever,"

and he is of opinion that "the disease is a soil disease, resembling in its propagation malarial diseases." This relation between this disease, and telluric conditions is very strongly supported by many observers, but, without doubt, depends upon contamination; for the dissolution and distribution of dilute sewage throughout the soil would be favourable to the development of typhoid bacilli, and there can be no doubt as to the truth of Sir Charles Cameron's statement that "a filth-laden soil is a good nidus for the bacilli of typhoid fever," and that "just in proportion as we preserve our soils from human excreta, may we expect to find a diminution of the amount of typhoid fever."

The same observer makes further statement that typhoid fever is a semi-miasmatic disease, and a disease of the soil, which resembles in its propagation malarial disease. It is highly probable that the culpable fouling of the soil practised by our forefathers, and continued by ourselves, has more to do with the propagation of disease than any property in the virgin soil itself, and that one of the chief means of the propagation of typhoid fever is through a special organism becoming endemic in the soil in close proximity to the patient's abode, or through it finding its way into milk and water. Sir Richard Thorne has observed that "the steady diffusion of typhoid fever on the appearance of a case in an insanitary area shows that enteric fever, though mainly distributed in epidemic form by means of water or milk, is by no means always a water-borne disease. It raises anew the question as to how far recurring prevalences of enteric fever in one town or in one spot can be due to the persistence, in more or less active form, in certain soils, of the organism of the disease." Dr. Sidney Martin has ascertained through the various experiments that "the bacillus of typhoid fever behaves very differently when, in the absence of competing micro-organisms, it is implanted in organically polluted soil and in virgin

soil." In soil of the first kind the bacillus grows rapidly, and spreads abroad; whereas in virgin soil, under like conditions of moisture and temperature, it languishes and quickly dies out. Mr. Adams points out the danger of infection through soil, and he classifies every soil through which foul surface deposits pass into three layers. First, the *danger* zone, containing many putrefying organisms; second, the *risky* zone, containing many nitrifying organisms; and third, the *safe* zone. He also lays stress upon the fact that, after long droughts, the surface-soil becomes fissured and cracked as it loses its cohesion, and thus foul surface deposits may be washed, by heavy rain, through, into the neighbourhood of the water zone, without having undergone any purification. The soil in a midden town is particularly likely to cause infection, for it is impossible to ensure disinfection of a midden which has been once polluted, and, as these receptacles are seldom impervious, the surrounding soil soon becomes saturated with infective fecal matter. Professor Delepine has found the bacillus of typhoid fever in the soil surrounding a midden. Since the bacillus of typhoid fever may germinate and multiply outside the human body, there is no apparent reason why it should not survive, under favorable conditions, for an indefinite period. Murchison adduced the fact that "single cases of typhoid fever do arise in the same house again and again at intervals of a year or longer"; and Sir Charles Cameron thinks that "this disease may cling to individual houses, and infect succeeding tenants." It is quite possible, also, that those currents of air sewage which arise from putrefying sources may pass, loaded with morbid matter, into a healthy zone, and so infect healthy persons.

It is now a settled fact that polluted water is the most important agent in the conveyance of enteric fever, and the slightest contamination of a water supply with the dejecta from a case of typhoid fever,

has, in many well-authenticated cases, caused widespread epidemics of the disease, which generally was confined to those persons who had used the polluted water supply. In many cases the amount of organic matter accompanying the specific pollution was so extremely small that the water supplies have been repeatedly proved by chemical analysis to be of high organic purity, but the bacillus of typhoid fever, when introduced into a potable water of good quality, may not only retain its vitality for a considerable time, but may multiply almost indefinitely. In addition to the typhoid bacillus, other organisms are found in water, and closely resembling the typhoid organism is the *Bacillus coli Communis*, which is a constant inhabitant of the intestinal tract and faeces of man and animals. Roux and Rodet believe that the *Bacillus coli Communis*, such as grows in sewage, etc., assumes a pathogenic character, and gives rise to a disease which is clinically undistinguishable from typhoid fever. Demel and Orlandi bear witness to these statements, and Germano and Maurea consider that *Bacillus coli Communis* may, under certain conditions, develop into *Bacillus typhosus*.

Professor Ray Lankester gives it as his opinion that the *Bacillus coli Communis* from the intestines of animals may become an adjuvant factor of typhoid fever if, by any chance, it finds entry into the intestines of man. He thinks that this bacillus is an innocent saprophyte which may alter its character and become possessed of intense pathogenic activity if it is allowed to associate with the same bacillus of an equally saprophytic nature in the intestines of man. These opinions of Lankester have been in some measure strengthened by the investigations of Drs. Lorrain-Smith and Tenant, and Sanarelli states that "when the typhoid process is set up, this bacillus acquires virulence, and takes active part in the disease, through auto-intoxication."

It has been admitted by many observers that cows

are able to infect milk, both before it leaves the udder, and after. Some observers believe that cows suffer from enteric fever, but, true or not as this may be, it is certain that epidemics of this disease do arise through milk, especially milk which has been adulterated with polluted water, or stored in vessels washed out with polluted water. Milk is an excellent medium for the cultivation of the typhoid bacillus, as it multiplies in milk enormously faster than in water, and a vessel left damp with moisture, containing only a few organisms, would be capable of infecting its entire contents of milk in a few hours. At creameries where the milk from a large number of farms is received every day, and mixed together before separation of the cream, there is a possibility that the milk from one infected farm might have contaminated the pure milk with which it was mixed, and convey the disease over a large area. An epidemic from typhoid fever due to milk supply has usually a sudden outbreak, many of the attacks being simultaneous; a large proportion of the households attacked have a common milk supply, and the incidence of the disease will be greatest on the principal consumers. Vegetables have been known to convey this disease, and oysters and other shellfish have been known to be sources of infection. The chief channel of infection between man and typhoid-infected soil is dust; and the *faecal debris* which may be carried in whirlwinds of dust may infect water or air, "and happy is the man who neither drinks the one nor breathes the other when so contaminated." It is a matter of frequent experience that cases of typhoid fever occur after exposure to sewer gas or vitiated air, which may or may not actually carry the specific germ of contagion, and the greatest incidence of attack is always heaviest upon houses or districts in which drainage defects exist. According to the Nottingham records, one in 101 houses with pail closets, and one in 360 houses with water closets were attacked with typhoid fever. The Belfast

records show that one in 108 houses with pail closets, and one in 400 houses with water closets were attacked with typhoid fever. The markedly beneficial effect of drainage and water supply upon public health is the great characteristic of the latter half of the present century ; but the maintenance of a water supply in a pure state is not of itself sufficient to eliminate typhoid fever unless the local hygienic conditions are good as well, otherwise the resisting powers of the human organisation will be lowered and less able to oppose the invading germs which may come from some other source. Professor Corfield is of opinion that defective sewers and drains are sufficient of themselves to cause an epidemic of typhoid, and this is borne out by the evidence obtained in Australia, where in cities where a good sewerage system has been installed heavy typhoid epidemics occur ; and inspection reveals obsolete house sanitary systems, broken water connections, cracked pans, faulty cisterns (in some cases not provided with water), choked drains, deficient ventilation, dirty dwellings, bath wastes connected directly with the main sewer and a general state of indifference as to keeping any sanitary system in proper working order.

People imagined that if in their old system of sewerage a trap existed the supreme end had been attained, forgetting that wherever you get stagnation you get putrefaction, and that the trap was useless unless properly ventilated and continually cleansed ; for the efforts of modern sanitary engineers are directed towards ensuring that the gases which inevitably result from putrefaction in sewers and house-drains, should be as much as possible diluted with the external air before we breathe them. In many of the hotels and principal eating-houses of the city, sewer gas was being absorbed by the man who was dining in what he thought was a properly-ventilated, comfortable and first-class dining-room. Supplies of drinking water, stored for domestic purposes, were collected in tanks which were so situated

that leaky and faulty water-closets placed on the floor above them, contaminated them with plentiful supplies of foul matter. The internal communications of a house, besides serving as a means of entrance and egress from the room, also, especially staircases, doors, passages, and faulights, serve as the means of supplying fresh air; but, if the sanitary arrangements of a house are bad, and the sanitary fittings are not arranged with due care, foul emanations will filter from wrongly-constructed drain-pipes, from ill-ventilated drain-pipes from old-fashioned water-closets, having no proper flush of water, and from untrapped house connections leading no one knows where; and the internal channels of communication in a house will, instead of serving for the supply of fresh air, merely facilitate the exchange of foul air.

The benefit accruing from a properly-installed sewerage system is well exemplified by the following table:—

MORTALITY FROM TYPHOID FEVER, CITY OF SYDNEY, PER 10,000 OF THE POPULATION.

—	Density of Population per acre.	Rate per 10,000 of Population.	
		Before laying Sewers.	Since laying Sewers.
City of Sydney	46.1	5.07	1.3
Glebe	37.0	2.5	1.1
Darlington	90.9	4.0	.4
Newtown	48.5	6.6	2.5
Redfern	55.9	3.6	1.0
Waterloo	11.7	1.2	.9
Paddington	48.3	2.7	1.5
Woollahra	...	2.1	.9

The prevention of typhoid fever can only be attained by observing cleanliness of body, securing pure air and pure water, and carrying out all the rules of modern sanitation; and it must be remembered that although the hope of totally avoiding, or

extinguishing altogether, infectious disease, is built upon a slight foundation, still there exists an enormous amount of actually preventible disease.

Erysipelas.—The chief evidence of this contagious and infectious disease is a spreading inflammation of the skin. The disease occurs everywhere, but it is supposed to be less frequent in tropical countries. Women are more susceptible to attack than men, but the mortality is greater among males. The predisposing causes are dirty surroundings, overcrowding, intemperance, and deficient nourishment. It is due to a specific microbe. *Streptococcus erysipellatis*, or *Streptococcus pyogenes*.

Glanders is a disease occurring among horses, mules, asses, etc., but rarely attacks man. In the human subject the disease is acute, and attacks the nose, forming nodular deposits in the nasal septum. The chief source of infection is the horse.

Hydrophobia is a disease which is, fortunately, unknown in Australia. The infection lies in the saliva of infected dogs, and can be communicated to man through a bite from the animal. It is almost always fatal, although of late years the genius of Pasteur has devised a remedy which has been the means of saving many lives.

Influenza is a contagious disease, characterised by a short period of incubation, a relative suddenness of onset as regards attack, rapidity of dissemination, and a general independence of climate, age, sex, or season of the year. The case mortality is variable, and is due in many instances to the indirect effect of the malady as expressed in the increased death rate from certain other causes. It is often accompanied by serious complications, and is usually followed by extensive and prolonged loss of strength.

Leprosy.—The sanitary inspector may be called upon at times to view cases of this disease, and he is referred for the fullest information to the work of

Dr. Ashburton Thompson on the subject. Leprosy, unfortunately, does occur in Australia, and is not limited in its attack to Asiatic races. According to the Leprosy Commission in India Report, p. 384 :—

- (1) Leprosy is a disease *sui generis* ; it is not a form of syphilis or tuberculosis, but has strictly etiological analogies with the latter.
- (2) Leprosy is not diffused by hereditary transmission, and for this reason and the established amount of sterility among lepers, the disease has a natural tendency to die out.
- (3) Though in the scientific classification of disease leprosy must be regarded as contagious, and also inoculable, yet the extent to which it is propagated by these means is exceedingly small.
- (4) Leprosy is not directly originated by the use of any particular article of food, nor by any climatic or telluric conditions, nor by any insanitary surroundings ; neither does it peculiarly affect any race or caste.
- (5) Leprosy is indirectly influenced by insanitary surroundings such as poverty, bad food, deficient drainage, or deficient ventilation, for these, by causing a predisposition, increase the susceptibility of the individual to the disease.
- (6) Leprosy in the great majority of cases originates *de novo*, that is, from a sequence or concurrence of causes, and conditions, which are related to each other in ways at present imperfectly known.

It is in Australia a compulsory notifiable disease.

Malaria.—" Covering a broad zone on both sides of the equator malarial diseases reach their maximum of frequency in tropical and subtropical regions. They continue to be endemic for some distance into

the temperate zone, with diminishing severity and frequency towards the higher latitudes ; in epidemic form they not infrequently appear in yet other regions, and in still wider diffusion with the character of a pandemic also beyond their indigenous latitudes." (Hirsch.) Season affects its occurrence but little, but the state of the soil in the etiology of malaria is universally recognised. It is due to certain amoeboid organisms which were first found in the blood by Laveran, and it is often communicated through the mosquito which Surgeon-Major Ronald Ross found to play the part of host to the parasite. It is prevented by due care of the soil so that it is efficiently drained and kept from being damp.

Measles.—From time to time Australia has been visited with disastrous epidemics of measles, a disease which occurs independently of climatic influences, and attacks all without regard to sex, age, or race. The mortality is usually greatest in the second year of life, and insanitary surroundings have a marked influence. It appears to be very fatal in coloured races, as is instanced by the epidemic in Fiji in 1874, where the mortality was tremendous. It is infectious with the earliest symptoms and the infectivity lasts over four weeks.

Plague. Bubonic plague has occurred in various parts of the globe, at various times since about 98 A.D. It is intensely contagious, and selects generally the poorer classes for its victims, or those living under circumstances of overcrowding. It is inoculable in certain mammals, and produces in them a disease similar to that seen in man. Its outset is usually quite sudden, and the plague patient is overwhelmed, has an indescribable odour, high fever, great thirst, and general disturbance of circulatory and nervous systems. The distinguishing character is an external bubo, or swelling, which generally appears within the first two days, usually in the groin, but many occur

in the armpit or neck. At any period of the acute illness carbuncles may occur in a small percentage of cases. The mortality is usually great, and death may occur in 24 hours or from the third to fourth day of the attack. According to Hirsch, "the development of plague always requires access of specific virus." This is now acknowledged to be the *bacillus pestis bubonicae* which has such pathogenic properties that it can exist in the body of man and of certain lower animals. Infection may be carried in clothes, rooms, soil, water, &c., and the disease may reappear in the same locality year after year. Plague is rarely conveyed by contagion from man to man, but there must be an intermediary host for the disease, and this host is the rat. The rat is naturally susceptible to the plague, and stands condemned as a source of infection for human beings. Dr. Frank Clemow says, "That rats may become infected from the soil is probable. It is among the oldest belief in regard to the causation of plague that the disease arises from some miasmatic exhalation from the earth. Modern observation lends little support to this view, but it has shown that the soil or its surface can, under certain conditions, receive and retain for a time the virus of plague in an actively infective state. If the soil is rich in organic matter, contains a certain amount of moisture, and is only exposed to air and light, it may retain the plague bacillus for a considerable period."

Scarlet Fever.—Ransome is of opinion that this disease which occurs sporadically from time to time, may trace its mortality "not only in a short cycle of four to six years, but also a long undulation of fifteen to twenty years or more; which may be likened to a vast wave of disease upon which the lesser epidemics show like ripples upon the surface of an ocean swell." Longstaff and Barnes find that "where scarlet fever is most prevalent, a particularly low diphtheria rate prevails." Climatic influences do not play a very important part in determining its geographical distribution, but season does influence

the prevalence of this disease. According to Whitelegge, the seasonal curve varies little from the mortality curve, but generally at the season of year it is most prevalent it is least fatal. One attack is usually protective, and the mortality is greatest at the age of three years. The disease requires a very strict sanitary control on account of its long period of infectiveness, and the readiness with which the poison is spread by means of the fine scaly particles which are diffused with the dust throughout the room. The poison clings for long periods with great persistence to clothing and articles of furniture; and Boobyer has recorded a series of cases, the incidence of which appeared to be determined by the disturbance of the soil. Milk has been proved to be the vehicle of the contagion, and the cow herself has been found by Power and Klein to be the source of infection.

Small-pox.—Known as this disease, has been for two thousand years the *pesta magna* of Galen, and the deracinator of peoples and nations, still thanks to an excellent system of quarantine, the disease is rare in Australia, and has never gained any great amount of headway when it has been by accident introduced. Its incidence is independent of climate or soil, and a heavier mortality is found among males than among females, and all coloured races appear to have a peculiar susceptibility to it. It is disseminated mainly by aerial convection, and is carried by epithelial *debris*, pieces of clothing, etc. Individual protection is obtained by vaccination. Barry says: "Out of 1000 persons over ten years of age living under the common conditions of infection, The attack rate in persons twice vaccinated was 3·00

"	"	"	"	once	"	"	19·00
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"	"	"	"	not	"	"	94·00
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The death rate in persons twice vaccinated was 0·08

"	"	"	"	once	"	"	1·00
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"	"	"	"	not	"	"	51·00."
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Re-vaccination, therefore, renews in all respects the immunity given by primary vaccination. The strict-

ness of quarantine, as carried out in Australia, appears to control the ravages of this disease.

Tetanus is a disease which owes its toxic principle to a specific microbe, which finds an excellent medium in the soil for the preservation of its life history.

Tuberculosis.—This is a diseased condition which occurs in man in a variety of different forms, the most familiar being phthisis, scrofula, lupus, tabes mesenterica, and meningitis. This disease is not in any way limited to the human race; it is very common among oxen and cows as a disease called "grapes." It also affects pigs, as well as fowls and rabbits. No climate is exempt, but it affects especially cold climates, and is frequently associated with a daily range of high temperature along with humidity of the atmosphere. With the exception of the Jews, no race is in any way exempt from tubercular disease. Coloured races seem to suffer much from phthisis, particularly if they become associated with conditions of higher civilisation. "Admitting the constant presence of the bacillus, we have, as in other specific diseases, to determine the power of resistance of the tissues to its invasion, and to note various other conditions as being also requisite for the production of the phenomena which we recognise as tubercular disease. In the case of tuberculosis, this is pre-eminently true, and these other conditions, or so-called predisposing causes, must be regarded as having an importance hardly second to the micro-organism itself." (Lanc Notter.)

Professor Nocard asserts: "It is the duty of every medical practitioner to preach that tuberculosis is a preventable disease, arising, in the majority of cases, from a contagion that is easily guarded against, and he points out that only about one-sixth of the cases of human tuberculosis could be attributed to heredity."

Sir Peter Eade says "that heredity in phthisis consists only in the tissues of some bodies, being so

constituted as to form an unusually suitable soil for the bacillus, and that if the germs of the disease can be kept away, these specially structured individuals will have a much greater chance of survival, even if they be somewhat more delicately constituted than their neighbours."

On this point, also, Sims Woodhead remarks: "The children of tuberculous parents can be placed under such conditions that they will never contract the disease. They do not inherit tuberculosis from their parents, though they may inherit those weaknesses of tissue and constitution which render them peculiarly liable to succumb to the attacks of parasites that in their parents are doing such damage."

There is no doubt but that it does spread at times by infection from case to case. "But it," says Sir William Broadbent, "is no longer to be regarded as a visitation of God, for it is now well known to be the result of man's ignorance and carelessness."

This disease is capable of being transmitted, either by aerial convection or by ingestion of food, through a specific virus or microbe which is a facultative saprophyte as well as a parasite, and is capable of growing in the organic matter contained in respired air, or in the vapour arising from the soil. It may be, and undoubtedly is, produced by the inhalation of specifically infected dust which contains micro-organisms of a pathogenic nature. These micro-organisms are the spores derived from dried and desiccated sputum which has been recklessly thrown out by the filthy, pernicious, and unnecessary habit of expectorating in public thoroughfares and conveyances. Tuberculous persons are a source of danger to others, chiefly through the sputum, and M. Cornet has shown that a very large number of these places where phthisical persons live and congregate, do contain material in the form of dust, which is capable of communicating tuberculosis. The danger of infection from the sputum is magnified through the fact that the bacilli of tuberculosis retain

their vitality for a long time after they have left the body in dust and dried sputum. Phthisis, or more properly, tuberculosis, is now acknowledged to be an infectious disease of a micro-parasitic nature, intimately connected with the dampness of soil. Buchanan has, by his experiments, conclusively proved that phthisis is intimately connected with dampness of the soil; and Bowditch, in America, remarks: "Residence near or on a damp soil, whether that dampness be inherent in the soil itself or caused by percolation from adjacent ponds, springs, rivers, meadows, or marshes, etc., is one of the principal causes of phthisis." "That phthisis is not readily communicated is certain, but it does seem to be so under certain favourable conditions, as in the case of husband and wife, and other persons living in close and habitual contact" (Lane Notter). Sanitary defects in houses are apt to cause a deterioration of the general health, and to predispose to infection; but infection itself, direct or indirect, is apt to be intensified, and its conveyance to be much facilitated by overcrowding. There is little doubt but that Davies is right in stating that "aggregation into communities with the inevitable resulting overcrowding of habitations, and the establishment of more sedentary occupations, gave the necessary encouragement to an organism, able to live and multiply favorably at the body temperature and in the body tissue, to select an appropriate site for its output, and so, in course of time, firmly to establish its continuance as a parasite." The virulence of the microbe of tuberculosis is diminished by currents of air and sunlight; or, as Manson describes it, "swilling and flushing with fresh air," but re-breathed air is a source of great danger, for stagnant air, charged with organic material, may maintain the virulence of the microbe for a long time after the bacillus has left the body. The operatives in certain trades are especially liable to be attacked by phthisis, particularly those in which there is excessive moisture or gritty particles.

That there is a possibility of tubercular infection through the alimentary canal is certain. As tuberculous disease in infants and young children is very often a disease with lesions of the cerebro-spinal membranes, or a disease affecting the intestines and their related lymphatic glands, there is good ground for belief that the infection in childhood *at least* finds its entry in a very large proportion of cases by means of the alimentary canal. This extension of infection by ingestion of food, points to an extension of bovine tuberculosis, which constitutes a serious economic loss and a new source of danger to man. Brown, of Carlisle, has pointed out that the tuberculous lesions in cattle have the same localisation as in the human subject; and other observers have laid much stress upon the infectivity of phthisis by means of milk. Sir Richard Thorne points out that "that form of tuberculosis which is caused through infection by means of the alimentary canal has steadily increased the number of its victims, and that the increase has gone hand-in-hand with the steady increase in the consumption of milk." The danger from milk may be lessened if it is pasteurised in small quantities, but at the present time there is no practicable and certain method for freeing milk on a large scale from germs, without, at the same time, seriously prejudicing its flavour and nutritive value. The report of the English local government shows that the milk from cows with tubercular disease of the udder is very infective, and that the tubercle bacillus is not destroyed, by ordinary cooking, if it happens to be in the centre of a joint of meat over six pounds in weight. The mortality from tubercular disease is enormous, and it is generally estimated at least $\frac{1}{4}$ of the total mortality. As a rule it is greatest among males, and the deaths registered fall from the first to the fifth year; after the age period 5-10 they increase up to the age period 25-35, after which they decrease, but are known at very advanced ages. Phthisical patients should

never spit in streets or public conveyances, but they should always be provided with a proper receptacle which can be thoroughly disinfected. Any rags used should be burned. Rooms and wards used by such patients should be well rubbed with half-baked bread, and there should not be any accumulation of dust. Ransome has proved that during the last thirty years there has been a steady diminution in the mortality from pulmonary phthisis in direct proportion to the improvement in general hygiene, and Sir Richard Thorne states:—"During the last half-century, sanitary improvements have reduced the death-rate from phthisis; at anyrate from that form which is due to aërial convection. By the effects of subsoil drainage, improved hygiene, raising of the general standard of cleanliness, both of person and dwelling, and the greater attention now given to ventilation, the mortality from tuberculosis has been decreased." Buchanan attributes much of the diminution of the phthisis death rate to that "drying of the soil which has followed upon the laying of main sewers." Since the institution of sanitary works we have witnessed an enormous decrease in the number of persons suffering from phthisis, and a decided lengthening in the duration of the disease. Sir Joseph Fayrer says: "Sanitation has done good by helping to improve the ill-ventilated, over-crowded dwelling, damp water-logged soils, and impure water. Through these improvements fewer persons die from phthisis and are slower to die when affected." Clearance of over-crowded building sites, and the reconstruction of insanitary house property are now most important factors in dealing with this disease, which annually claims its holocaust of victims, and through which, Francis Fox states, "Great Britain loses annually 70,000 souls because people do not understand the value of fresh air." The value of sewers in reducing the death rate from phthisis is shown by the following table:

MORTALITY FROM PHTHISIS.

		Density of Population per acre.	Rate per 10,000 of Population.	
			Before Laying Sewers.	Since Laying Sewers.
England	Salisbury		44	22
"	Ely		31	16
"	Rugby		43	10
"	Banbury		26	16
"	Macclesfield		51	35
Sydney, N.S.W.	City	46·1	13·6	9·2
"	Glebe	37·0	11·5	6·2
"	Darlington	90·9	8·0	2·6
"	Newtown	48·5	6·1	3·9
"	Redfern	55·9	12·1	5·2
"	Waterloo	11·7	15·9	6·4
"	Paddington	48·3	13·6	7·2

CHAPTER VII.

DISINFECTION.

The general measures to prevent the spread of disease may be divided into two classes :

1. (a) Vaccination ; (b) Quarantine ; (c) Notification and Isolation.
2. Disinfection of the Person, Clothes, Home, and Discharges of the Patient.

Vaccination.—The disaster which periodically befell nations in Europe through visitations of small-pox, both in the mortality accruing and the hideous disfigurement of the features, roused all scientists to their best endeavours to avoid the disease. From time immemorial *benighted* China combated this disease by *inoculation*, and thence it was by some means introduced into Turkey, where its prophylactic powers were readily recognised by Lady Mary Wortley Montagu, who, by her example and letters, made it popular in 1721. In China, inoculation was practised by putting variolous crusts into the nostrils, but in 1798, as “the fruit of his scientific temper and indomitable perseverance,” Edward Jenner perfected his—“The Greatest Achievement of Medicine”—scheme of vaccination. Vaccination, which is much milder in its effects than inoculation, although it does not absolutely protect from small-pox, modifies any attack and prevents the hideous mortality which existed before its use.

Quarantine has been described as an elaborate system of leakiness, and De Chaumont has characterised it as “absolutely useless, as it interrupted business and delayed travellers, without doing any real good.” Maybe this is in some measure true, but if it is only rigidly enforced in times of special danger its action

is most beneficial, and Australia has to thank its quarantine system for its freedom from such disastrous diseases as small-pox.

The compulsory notification of infectious diseases is without doubt one of the most valuable aids known in stamping out disease ; for it not only acquaints the local authority of the fact of such disease existing, but it also allows for inspection and localising the source and locality of such disease.

Isolation.—Once an infectious disease has established itself, and spreads from one person to another, isolation is perhaps the greatest prophylactic measure which can be insisted upon. It cannot be insisted upon too strongly, and no one can for one moment raise any question as to its necessity, nor yet of its efficacy. Rigid isolation should be practised in all diseases of an infectious nature, and especial study should be made of the methods by which the infection is carried.

Disinfection of the Person.—One of the first things needed in dealing with disease is that there should be a true appreciation of individual responsibility. Every citizen ought to clearly understand that it is his duty to the State and to his fellow-citizens to exercise all due precaution, and prevent, as far as lies in his power, any possibility of disease being carried through any act or neglect of his own. Personal disinfection has been called the "*last line of defence*," and it includes cleanliness of home, cleanliness of person, and purification of the clothing.

"A true disinfectant must not only mask the smell, but must destroy the germs which give rise to it." "Man has an instinctive repugnance to all noxious odours, and from the earliest times has sought to mask their presence by the use of aromatic substances." Upon the view that germ life of definite morphological character constitutes in itself the *contagium vivum* of contagious disease, it appears that the best agents to employ for its destruction are those which have the

power to arrest vital action. This is true as regards those diseases which are undoubtedly due to the spreading of parasites ; but the infectant, although it may be killed in one part of the body, may re-appear in another part, and may exhibit a very tenacious power of resistance." Fortunately, by far the greater number of pathogenic germs given off from any case are destroyed by what we may term *natural disinfection*,—by the action of light, air, or by meeting with conditions of soil and temperatures unfavourable to their growth. The biologist shewed that decay was due to the action of living organisms floating in the air, and that the ideal of disinfection was to stamp out the pathogenic bacteria, just as weeds are extirpated from a garden. It has been said that there is no reason at all for the existence of infectious disease, and if only true measures of precaution were adopted, infectious disease would disappear. If, however, we wish to carry out this idea, we must first of all cease hiding smells with other smells, and cease to think that the creation of a rival smell, is a criterion of safety. The natural processes which obtain in a healthy individual, and the improvement of his environment by hygienic measures, assist in the annihilation of those causes by which diseases arise.

Light, God's eldest daughter, is a most powerful germicide, for it has in the presence of air a deleterious action on bacteria, and cleanses the house which is bathed in its purifying influence. The mechanical purification of gases and liquids by inert substances, aids in the improvement of man's environment ; and the sand filtration of water, by purifying this essential of life, helps to render that life sweeter.

Practical Disinfection of Rooms.—"As by far the greater number of bacteria must be on the floor, it is important to destroy them first, and not to allow them to be stirred up into the air by the movement of those engaged in the subsequent operations. To ensure this, the floor and carpet should be liberally

sprinkled with sawdust mixed with 10 per cent. by weight of crude carbolic acid, or with a solution of mercuric chloride (1 in 1000). A fire should be then lighted in the room, both to cause the air in the room to leave it by the chimney, and to be available for burning anything that is sufficiently valueless to be destroyed. All hangings, bedding, and clothes should then be removed to a steam disinfectant, and the walls and ceilings washed down by means of a whitewash brush and a solution of mercuric chloride (1 in 2000), or bleaching-powder (6 ounces to the gallon); the furniture is to be taken out of doors and scrubbed. The wall-paper is stripped and burned without being taken out of the room, and the carpet is taken up and sent to the disinfectant. The sawdust should be rubbed on the bare boards, so that the bacteria may stick to it, and then swept up and burned. After this the floor should be well scrubbed with soap and hot water; the ceiling lime-washed, and the walls re-papered before the room is re-inhabited." In dealing with disinfectants formed of chemical compounds, it is important to distinguish between an antiseptic, which simply stupefies the germs of disease for a time, and a disinfectant which kills them and leaves the room sterile.

Chlorine.—By mixing dilute hydrochloric acid or dilute sulphuric acid with bleaching powder, chlorine is evolved. As a disinfectant, chlorine may act by,—replacing the hydrogen in the organic substances, so that the bacteria die and innocuous compounds are formed;—decomposing the offensive gases of putrefaction;—acting as an oxidising agent. The last is the common and most important action of chlorine, but needs the presence of moisture for its effect, in fact it is necessary to fill the room with steam some hours before the chlorine is used. Sprinkling or spraying rooms with disinfectant solutions is a true scientific method, for,—“we are not dealing with an unknown virus any longer in the case of most diseases, but with numberless small organised vegetable

structures, the death of all of which can be assured if they are brought into contact with proper re-agents."

Rideal says that 3 lbs. of chloride of lime and 3 lbs. of hydrochloric acid should be used for every 1000 feet of cubic space, while Koch places the quantities at 15 lbs. of bleaching powder and 22 lbs. of hydrochloric acid. The weak disinfectant power of chlorine, and the disadvantages attendant upon its preparation, lead to its being rarely ever used, and its place has been altogether taken by sprays containing bleaching powder or chloride of lime, which is really a mixed chloride and hypochlorite.

Sulphur:—

"Next with pure sulphur purge the house, and bring
The purest water from the freshest spring;
This, mixed with salt, and with green olive crown'd,
Will cleanse the late contaminated ground."

—THEOCRITUS.

In the same way as with chlorine, for the effectual disinfection by *Sulphur*, everything in the room must be made moist. The burning of sulphur (1 lb. for every 1000 cubic feet of space) generates sulphur dioxide, or sulphurous acid gas, and this acts as a disinfectant, in that—it absorbs ammonia, organic bases, and the products of growth of pathogenic organisms;—it reduces organic matters or combines with them to form compounds which are in most cases inert;—as a poison it kills living organisms. One of the objections to the use of sulphur as a disinfectant, is its bleaching action on fabrics, and the danger likely to accrue through the fire used. The latter objection, however, is overcome by using liquid sulphurous acid, sold compressed in tins, from which it is allowed to vaporize slowly through a metal pipe.

Permanganate of Potash, commonly known in the form of Condyl's fluid, exercises its disinfectant action through its power of evolving oxygen. It is only a local disinfectant, however, and is objectionable on

account of the brown stain it leaves on fabrics. This stain if exposed to the fumes of burning sulphur disappears.

Mercuric Chloride, or "corrosive sublimate," is a most powerful disinfectant, but, as it is exceedingly poisonous, it must only be used with the greatest possible care. Klein is of opinion that although this salt is an efficient germicide, yet that Koch and others have overrated it; and Calvert is of opinion that it "destroys vibrios but not fungi."

Carbolic Acid is certainly antiseptic, but opinions differ as to its disinfecting power. Wolfhüggel and Von Knorre find that, when disinfection is to be completed in less than twenty-four hours, carbolic acid is useless.

Sanitas, by its power of forming ozone, has a purifying action, and is also a disinfectant of good power.

Formaldehyde, or Formalin.—This salt is readily soluble in water, and is stable in solution. It is not a poison, but, according to Loew and Fischer, is possessed of very powerful antiseptic properties, and as its solution is without any ill effect on clothes it is especially suited for using in the form of a spray. It is possible to destroy bacteria through the action of formalin, and to thoroughly sterilize and disinfect rooms. The method of disinfection is either by a spray or by heating the salt to evaporation over a spirit lamp. /gas

Disinfection by Heat.—It is well known that boiling for a sufficiently long period, effectually destroys all organisms, and in short, *sterilizes*, as it is called. This process is, of course, effective for disinfection where it can be applied. In many cases, however, its use is impossible, either because of practical difficulties in its application, or because the process would destroy the article to be disinfected. The application of heat in some other manner, which

should be free from those defects, was therefore suggested, and endeavours have been made to apply—1st, heated air; 2nd, steam; and 3rd, a combination of heated air and steam. It has been found that there is a marked difference between the action of dry air and steam, or, as they are sometimes distinguished, dry and moist heat, in their powers of disinfection. The temperature necessary to effect the destruction of infectious matter, is very much higher in the case of dry air than of moist heat, so high, in fact, that in many instances, fabrics would be charred, and so destroyed, before the organisms to be destroyed were killed. Another defect in the action of dry air, is the difficulty of ensuring equal diffusion of the heat; that is, equal temperature throughout all parts of a dry-air disinfecting chamber, and also the fact, that the heat, as carried by dry air, penetrates articles which are good non-conductors, such as bedding and such-like, with much greater difficulty than does steam or moist heat.

The difference between moist and dry heat in its action on living organisms is plainly suggested to us by their effects on human beings. For instance, it is well known that 100deg. to 110deg. Fah. is the highest temperature at which the body can endure a water bath, and any one falling into a tank of boiling water, which is usually at 212deg. Fah., would be at once killed. But, on the other hand, dry air temperatures far above 212deg. are readily endured by our bodies. The temperature of 300deg. Fah. is occasionally provided in the dry air of the hottest room in a Turkish bath. It is on record that a man has sat in a dry air temperature of over 400deg. Fah. while a plate of meat placed beside him was cooked. With moist heat it is entirely different. Moist steam at 212deg. will scald a man to death, just as boiling water would; but dry or superheated steam would not do so, but would act more like dry air in this respect. It has been stated that an exposure of bedding to a temperature of 250deg. Fah. for nine hours

is generally sufficient ; but exhaustive tests as to this sufficiency, in all cases, are still lacking. Further, it is almost certain that the exposure of woollen articles to a temperature of 260deg. Fah. for nine hours would deteriorate them, and charring or singeing may be evident under such conditions, at a temperature of 280deg. Fah. The margin of safety to the articles is thus very small, even presuming that disinfection will be effective in all cases at 250deg., which is more than doubtful. Another danger present with dry air, but absent with moist heat, is the danger from fire, due to the ignition of inflammable substances, such as matches left in the pockets of clothing, or even greasy cotton fabrics or waste.

Moist heat, which is usually applied in the form of steam, appears to be the safest and most effectual, as well as the speediest form of disinfection by heat. There, are, however, several points of importance in the use of this medium. A knowledge of the properties of steam teaches us that its temperature increases with the pressure, and, that a lowering of the temperature (at any pressure) by contact with cooler bodies, leads to the condensation of the steam in the form of boiling water on the surface of the cool body. Both of those points are important in steam disinfection. Increased pressure and temperature result in greater penetrating power and speedier action in destroying life. For this reason steam at from 10lbs. to 20lbs. pressure over the atmosphere is often employed. The employment of steam under any considerable pressure, however, leads to difficulty and increased cost in the construction of a disinfecting chamber. Recently the advantage of increased pressure has been obtained in another way, namely, by providing means for partly exhausting the air in the apparatus before admitting the steam. Thus, a vacuum of 10lbs., followed by steam under 10lbs. pressure, is equivalent to a difference in pressure of 20lbs. as penetrative pressure, besides having the advantage of partially exhausting the air from

the interstices of the articles to be disinfected, and so rendering the access of the following steam more easy. Further, in this way, the maximum pressure inwards or outwards on the disinfecting chamber, is only 10lbs. per square inch instead of 20lbs., as in the case of the equivalent, but less effective pressure of 20lb. steam.

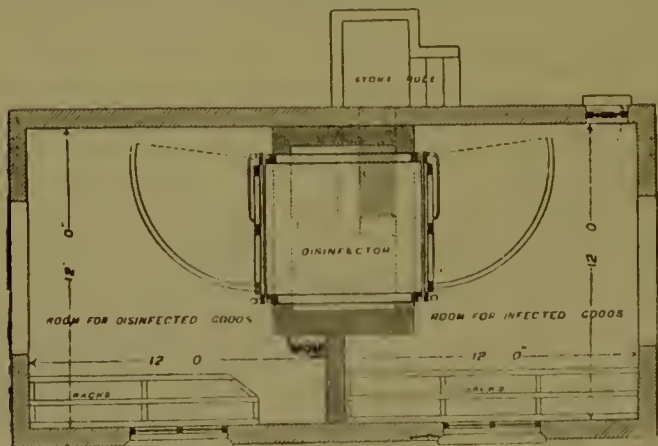
The difference in effect was shown in an experiment conducted in a "Washington-Lyon" machine. Here a bale of pressed cotton rags, 3ft. 6in. x 3ft. x 2ft. 3in., was found to be heated to a temperature of 258 deg. Fah. in its centre in four hours, by steam alone, while a larger bale of similar material, exposed to the vacuum process before steam, was heated to 220 deg. Fah. in 45 minutes.

The condensing of steam in contact with cool substances is of much importance in a disinfector, for it is evident that the condensation of boiling water on many substances would entirely destroy them, being, in fact, exposing them to partial boiling. At the same time this very condensation is a powerful factor in assisting the penetration of moist heat into the body of the article to be disinfected. Steam at 10lbs. pressure in condensing to water, contracts $\frac{1}{1000}$ th part of its volume, and, in doing so, gives out over 900 units of heat. This enormous contraction, of course, greatly aids the penetration of the following, uncondensed steam, and the enormous latent heat rendered sensible, quickly raises the temperature of the substance. These are the advantages, and if not carried too far, condensation is in every way a benefit, that is, so long as it produces no more than a mere dampness in the article being disinfected. Great care, however, is necessary to ensure, that excessive condensation does not take place, and means are adopted to this end in all first-class disinfecting apparatus.

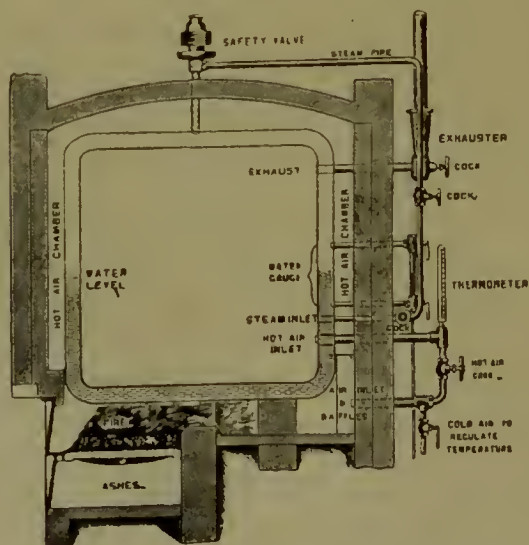
In the two forms of steam-disinfecting apparatus most commonly used in Britain, both of which are modifications of the "Washington-Lyon" apparatus,

THE WASHINGTON-LYON STEAM DISINFECTOR.
(GODDARD, MASSEY & WARNER'S PATTER.)

FIG. 12.



PLAN OF DISINFECTOR AND DISINFECTING ROOMS.
FIG. 11.



CROSS SECTION THROUGH DISINFECTING CHAMBER

undue condensation is sought to be prevented by—*first*, keeping the enclosing walls of the apparatus at a temperature somewhat higher than that of the steam entering the chamber; and, *second*, by heating the surface of the articles to be disinfected by a current of warmed air, preliminary to the admission of steam. This arrangement not only prevents the condensation of the steam in the body of the chamber, but the preliminary dry heating obviates the deposit of moisture on the contained articles, which is certain to take place when cold articles are exposed to the action of the steam. The combination also enables these disinfectors to be used for dry heat alone, where desired. This is a very great advantage, because certain materials, such as leather, furs, or glued, or varnished woodwork would be absolutely destroyed if exposed to moist heat, and so must always be treated by the dry process. The diagrams, Figs. 11 and 12, show a plan and cross section respectively of the “Washington-Lyon” apparatus, as manufactured by Messrs. Goddard, Massey and Warner, of Nottingham. The drawings explain themselves, and the plan in addition, shows the arrangement which should always be adopted for keeping the infected goods entirely apart from the disinfected articles. It will be observed that there are two distinct rooms, having separate entrances for this purpose. The disinfecting chamber is erected between these rooms, and it also, has two doors, one for the entrance of the infected goods opening into the receiving-room, and one opening into the other room, for their removal from the chamber after disinfection. It will be seen that the whole apparatus is very compact. The hollow casing to the chamber also forms the steam generator, the heat being applied over the bottom, while the space between the brickwork and the outside of the chamber casing, around the sides, and on the top, forms the air-heating chamber. The air is thus entirely heated by the water and steam surfaces of the boiler, and therefore

cannot be overheated so as to char the goods exposed to it, which is a most important point. The two doors are also steam-jacketted.

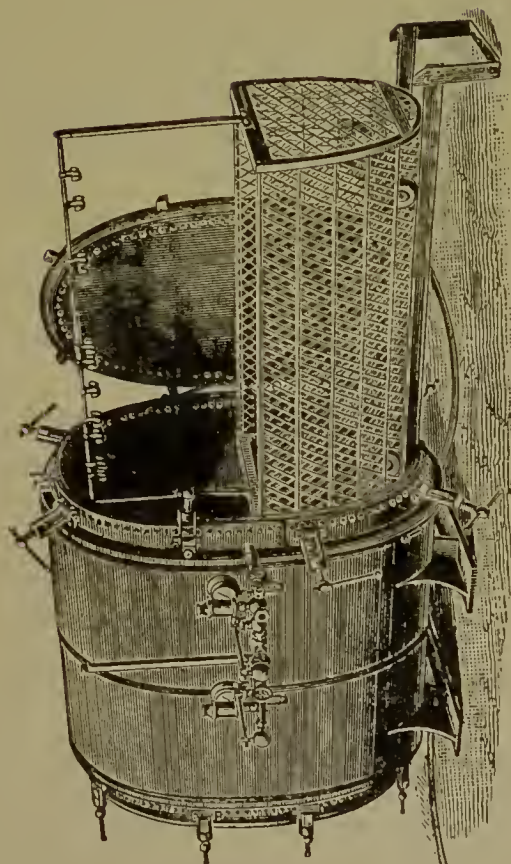
The method of operating the apparatus is as follows: Steam having been raised to about 10 lbs. pressure, the doors are opened, the articles placed in the chamber and the doors closed. Hot air is then drawn into the chamber for about ten minutes. A certain degree of vacuum can then be obtained by continuing the action of the steam jet exhauster, the hot air-cock being closed. Steam, which by this time should be about 20 lbs. pressure, is then admitted for a period, which varies with the kind of infection being dealt with. Finally the steam cock is closed, and the exhauster and hot air current again brought into requisition to dry the goods, and the process is complete. The size of the chamber, which is rectangular in section, is usually 5 ft. x 5 ft. x 6 ft. 6 in. long internally, but smaller sizes are made.

The other form of the Washington-Lyon disinfector, as made by Manlove, Alliott, and Co., also of Nottingham, is shown in Fig. 13. It will be seen that this apparatus is oval, or round in section, which is of course, a stronger form to resist steam pressure than is the rectangular. The larger size has a chamber measuring inside 7 ft. long, 4 ft. 2 in. high, and 2 ft. 7 in. wide. The more recent forms are fitted with an efficient vacuum attachment and the air is heated in pipes surrounded by steam. For this apparatus a separate steam boiler is needed, but a smaller portable form mounted on wheels, for country work, is also made, wherein the jacket is used as the steam generator, in a manner similar to the Goddard pattern. The steam pressure in the jacket is from 25 to 32 lbs., and that in the chamber from 20 to 22 lbs. The sequence of operations is much the same as in the Goddard pattern.

Rideal has pointed out that the time required for disinfection in steam disinfectors depends on three

THE WASHINGTON-LYON STEAM DISINFECTOR.
(MESSRS. MANLOVE, ALLIOT AND CO.'S PATERN.)

FIG. 13.



main factors—1st, the particular disease germ to be dealt with ; 2nd, the nature and bulk of the articles to be disinfected ; and 3rd, the pressure of the steam used. In regard to the first point he states that anthrax spores, which have hitherto been found to be among the most persistent forms of organism affecting human beings, can be destroyed with certainty by a fifteen-minutes' free exposure to saturated steam at 212° Fah. A five-minutes' exposure gave doubtful results, and he concludes that probably safe disinfection cannot be effected with a less exposure than ten minutes, and adds that the latter period is also sufficient to kill lice and their eggs, "for which purpose these machines are sometimes entirely used." It should be noted that these periods must be counted from the time when the heat has penetrated throughout the articles being treated. This period depends on factors 2nd and 3rd. In some experiments made by Dr. Whitelegge with a Manlove pattern disinfector, it was found that, with articles such as rolled-up blankets, bedding, etc., it took from fourteen to twenty minutes for the centre of the articles to attain a temperature of about 220° Fah.

Disinfection of Premises.—To see to the efficient disinfection of premises, and their contents, is one of the most important duties with which the Sanitary Inspector is charged. He must, therefore, be familiar with the means and methods recognised as efficient for the purpose. The following quotations from the instructions issued on this subject by the New South Wales Department of Public Health are given, because they not only put the requirements simply and clearly, but because they may be taken as indicating in an official manner the nature of the proceedings in disinfecting premises deemed necessary by Australian Medical Authorities :—

" *What Disinfection Is.*—Thorough cleansing in the usual household sense is an important part of

disinfection. But, as it is not always possible to remove the minute, living, particles of infection by cleansing, however thorough it may be, special methods have to be employed which can be relied upon to kill the particles where they lie hid, and so to render them harmless. Use of these special methods is called "disinfection." Hence the making of an infected thing not infectious is usually referred to as "cleansing and disinfection," for both processes are necessary.

Action of Disinfectants.—There is nothing mysterious about disinfectants ; they are not charms. They are used to do certain definite work ; namely, to kill the living particles of infection. They must, therefore, be applied intelligently, and according to three fixed rules. The first rule is that they must be capable of doing the required work—that is, they must be of certain suitable kinds ; these are named below. Secondly, they must be used of certain strengths, which also are mentioned below ; they must not be used weaker, but no other harm than waste will be done by using them stronger. Thirdly, though chosen of suitable *kinds*, and used in proper *strengths*, they must still be allowed sufficient *time* in which to act ; the proper times, again, are stated below, but it will not matter if they are exceeded.

Kinds of Disinfectants. The disinfectants recommended are of three kinds ; gaseous (for fumigation), liquid, and solid ; each has its proper use. The fumigating disinfectants are paraform, and sulphur. The liquid disinfectants are formalin, and carbolic acid. The solid disinfectant is chloride of lime ; but this can also be used as a solution. There is also one simple process which is thoroughly efficient ; this is boiling in water, or in water containing soap and soda, just as in ordinary laundry washing ; but to disinfect, the boiling must be continued for half an hour.

Paraform is sold in little white tablets. They are used by being heated over a spirit-lamp made for the

purpose, when they gradually turn to vapour and disappear from sight into the air. Twenty tablets are enough for a room of 1000 feet cubic capacity, and two more must be added for each additional 100 feet or part of a hundred. Paraform is not poisonous. It does not injure any articles exposed to its vapour. The vapour is very irritating to eyes and nose at first; but it can do no harm, and the irritation soon passes off.

Sulphur.—Roll or rock sulphur is to be preferred, because it can be made to burn better than the flowers. It is used by being broken into pieces between the size of a cherry and a loquat, placed in an iron vessel supported over a tub of water, wetted with a little methylated spirit, and set on fire. In burning, the sulphur turns to a vapour which fills the room. One-and-a-half pounds of sulphur is enough for a room of 1000 feet of cubic capacity, and proportionately more must be burnt for each 100 feet above 1000. A little more than the strict proportion should be taken because the whole never burns off. The vapour produced by burning sulphur (sulphur dioxide) is also sold in tins, in which it is condensed to a liquid which turns to gas again as soon as it is liberated; this may be substituted for burning sulphur, and then there is no risk from fire. Sulphur is not poisonous. Its vapour is irritating, and must not be breathed while it is strong.

Formalin is sold in bottles which hold 16 fluid ounces. For use, one part of formalin is to be mixed with nineteen parts of water—*i.e.*, one bottle of formalin and nineteen bottles of water, or one tablespoonful of formalin and nineteen tablespoonfuls of water, &c., &c. Formalin is not poisonous.

Carbolic Acid is sold of many different qualities. The most refined is white, the less refined is brown. The brown is the proper quality to use for disinfecting. That known as Calvert's No. 5 is a suitable quality. It is to be prepared by stirring half a pint up in

later 30
Acid 15
is 15 29
225

water and gradually making the quantity up to 1 gallon. Carbolic acid is poisonous, and before being diluted it burns the skin.

Chloride of Lime, or bleaching powder, is used in its solid form to sprinkle over the contents of cesspits, or other masses of filth before removing them, and on the ground after they have been removed, and to sprinkle in gutters, ditches, &c., &c. A solution can be made from it; and this is to be done by stirring up half a pound in a gallon of water. The liquor may be used before or after settling. Chloride of lime loses its virtue if left exposed to the air, and should be kept in tightly-closed receptacles. It is ~~not~~ poisonous.

To Disinfect Linen and Woollens.—All linen and woollen articles which have to be sent out of the room, while the illness lasts, are to be soaked in a tub partly filled either with the solution of formalin or of chloride of lime, or of carbolic acid. They must be allowed to soak for two hours at least; they may then be wrung out and sent out of the room to the wash. At the laundry, the articles which have been soaked should be first boiled for half an hour, and then finished in the usual way. If they cannot be boiled (blankets, woollens, etc.) they should be hung exposed to light and air for many hours, and then washed.

To Disinfect Hardware.—Cups, glasses, plates, knives, forks, etc., etc., and other articles of table-service should be soaked in either of the solutions of formalin, or chloride of lime, or carbolic acid, for two hours at least, before being sent out.*

To Disinfect Excreta and Discharges.—The patient's excreta, liquid as well as solid, must be received into vessels always kept ready, and containing at least a quart of either of the three solutions; they must be thoroughly stirred, and, if necessary, broken up with a piece of stick, so that they are really mixed with the solution, and before

*Those substances, with the exception of formalin, are corrosive to metals.

being disposed of must be allowed to stand for two hours at least. The infection in them will then be killed, and they may be disposed of in any convenient way. Other discharges must be similarly dealt with by being mixed or treated with an excess of either of the three solutions. If there is a fire in the room it is better to use old pieces of rag, or soft Japanese paper, which can be burnt, than pocket-handkerchiefs, etc.; however, if handkerchiefs and diapers have to be used, they should be changed before they have time to get dry, and must be steeped in either of the three solutions for two hours at least before being sent out of the room. Should the night-dress, bed-clothes, floor, etc., become accidentally soiled with any discharge, the spot must be at once wetted with any of the three solutions, and kept wet so as to kill the infection before it has time to dry. From what has been said above of infection it will be perceived easily that dust must be very dangerous. With wetted dust (or mud) there is little danger, if ordinary care be used, because it cannot fly about.

Preparation of the Sick Room for Fumigation.—After the patient has left his room it must be prepared for fumigation. This would be done best by the person who has nursed him. First of all prepare sufficient tubs containing either of the three solutions, and place in them all those pieces of soft goods which can be so treated without spoiling; put the tubs against the wall out of the way; turn the contents over from time to time; leave them until the fumigation is completed. Arrange all other soft goods, which cannot be so treated, so that the fumes can reach them on both sides; a good plan is to stretch a couple of lines across the room about a foot apart, and to hang each article spread out over both lines. Arrange all other articles so that the fumes can reach them all round as much as possible. Open all drawers and cupboards, so that the fumes can enter them freely. Paste a sheet of paper over the fire-

place, and over all air-bricks and ventilators, and strips of paper over the erevices round the window-frames, so as to prevent the fumes from escaping. Ascertain the size of the room. Take the requisite quantity of paraform or sulphur. See that the lamp or the iron dish is safely arranged so as to avoid risk of fire. Light the paraform lamp, or the sulphur (as the ease may be), shut the door of the room, and paste up the eraeks round the door and the keyhole on the outer side. If paraform is used leave the room closed for six hours at least ; if sulphur, then for twelve hours at least. At the end of that time throw the door open. The fumes of paraform are pungent, but can do no harm. The fumes of sulphur must not be breathed while they are very strong. As soon as possible the windows may also be opened.

Cleansing the Room after Fumigation.—Proceed to complete the disinfection by cleansing everything in the room thoroughly. Go over every article separately with a cloth moistened with either of the three solutions ; take care to wet and wipe all dust from them ; if pictures have been left on the walls take them down, wet and wipe all dust from eorners, mouldings, and backs ; go over each piece of furniture separately, take the bedstead to pieees, wash all dust out of eorners and angles, and the parts not usually seen ; go over the inside of all drawers and cupboards ; go over the skirting boards. Thoroughly wet the floor with one of the three solutions, and afterwards serub it in the usual way.

Cleansing Walls.—Walls, if colour-washed or kalsomined, should be done over again. If hung with varnished paper, or painted, they can be washed down with the cloths wetted in either of the three solutions. If hung with paper, it is best to remove and burn the old paper, and hang a new one ; if this cannot be done, and the paper will not bear wetting without spoiling, it may be thoroughly rubbed with



‘ALFORMANT LAMP.’—‘B.

stale bread, the crumbs being carefully gathered and burnt. Never paste a new paper over an old one; always wash off the old one first.

To Disinfect Bedding, &c.—Beds, mattresses, and pillows should be opened along the seams, and the filling spread on the floor of the room before beginning the fumigation; the coverings should be put in the disinfecting tubs at the same time. The coverings can afterwards be boiled. Horsehair may also be soaked in the disinfecting tubs. Feather, flock, and kapok should be spread in the sun for a day or two after the fumigation.

To Disinfect Upholstered Furniture.—Upholstered furniture should not be left in the sick-room. Any which has been so left should be fumigated with the other things, and afterwards taken into the open air, well beaten with sticks, and left exposed for a day or two.

To Disinfect Curtains, Heavy Clothing, &c.—Heavy clothing, curtains, silks, &c., which have been (improperly) left in the sick room, and which cannot be washed, must be taken out of doors after the fumigation and left exposed for a day or two, being so turned occasionally that every part may be exposed to sunlight and air.

Airing the Sick-Room.—After everything has been washed and cleansed, the windows and doors should be set open, and the room be left freely exposed to light and air for a time.

Disinfection of Closets.—Closets should be specially disinfected during the illness and after it is over. A water-closet should be treated by discharging a couple of buckets full of hot soap and soda very rapidly into the basin; then a similar quantity of clean water; lastly a bucketful of disinfectant solution of either kind; this is called flushing, which consists in feeding to the pipe-drain a larger quantity of liquid than it can carry off at once, so that it runs

full-bore. Flushing cannot be done by setting a tap running. Yard-gullies and other house-drains may be similarly treated to disinfect them. A pail-closet is to be disinfectcd by getting the pail thoroughly scrubbed out with chloride of lime solution. Treat a cesspit by first freely serving it with solid chloride of lime. After a time cause it to be emptied ; then serve its walls freely with chloride of lime solution. Afterwards scrape its walls, remove the bricks if it be lined, and fill it up with clean earth. Move the house a little to one side, and fit it with a pail. If the house cannot be moved, build a brick pillar up from the bottom of the pit to the surface, fill up with clean earth, well rammed, and lay a square of concrete for the house to stand on and to form its floor. It is necessary to deal thus with cesspits after every infectious disease, but especially so after typhoid fever. Cesspits are dangerous things, and pails should be substituted for them everywhere that sewers and water-closets are not available.

Destruction of Infected Articles.—The only articles which always must be burnt are books, papers, and toys ; they cannot be safely disinfectcd. It is rarely necessary to destroy any other infected articles. Things which can be boiled need never be destroyed. Articles which might be disinfectcd are sometimes so old, worn out, and filthy, that it is not worth while to spend time in attempting to cleanse them ; or of no value (as the straw filling of a mattress, for instance), so that there is no reason for wasting time in disinfecting them. In all other cases, though destruction of articles by fire is a short and certain way of getting rid of infection, it is unnecessary and extravagant.

Municipal disinfection of some articles.—In municipalities provided with a disinfecting station and a steam disinfecter, it is better to get many articles taken there, and disinfectcd by steam. Such articles are—bedding stuffed with feathers, heavy clothing,

carpets, &c., &c. In municipalities which possess a disinfecting staff, it is easier and better to call upon the latter to disinfect houses and rooms as well."

These instructions pretty well cover the whole subject; but the following additional notes will be of service :—

Disinfection by Chlorine Gas.—Chlorine gas is used for disinfection of premises, &c., as follows :—Chloride of lime is placed in dishes distributed through the room and placed as high as possible, so as to effect diffusion. Over these, funnels or filters are placed, partly blocked by a cork perforated with a small hole, so that the contents may drop gradually from the funnels. These are filled with ordinary hydrochloric acid. The room should be closed as above described for fumigation. Whenever the acid has been poured into the funnels, the operator should make haste to leave the room as the fumes are most dangerous. The room is left closed for 24 hours. Special precautions are necessary in opening the room. The doors of the other rooms should be closed and the windows opened. The operator must cover his mouth and nostrils tightly with a cloth dipped in a weak solution of ammonia, then rapidly open the door of the room which has been disinfected; throw open the windows, and retire without delay, closing the door behind him. All metal articles should be removed from the room before disinfection, or if fixtures, they should be rubbed over thickly with vaseline or lard to prevent their corrosion by the gas. Three lbs. of chloride of lime and 3 lbs. of acid should be used for every 1000 cubic feet of space.

Rideal has pointed out that in disinfection both by sulphurous gas, and chlorine, moisture is necessary for thoroughly effective action, and, therefore, recommends that a large vessel of water should be boiled in the room for some hours before disinfection, so as to saturate the air with water vapour and so make it thoroughly damp.

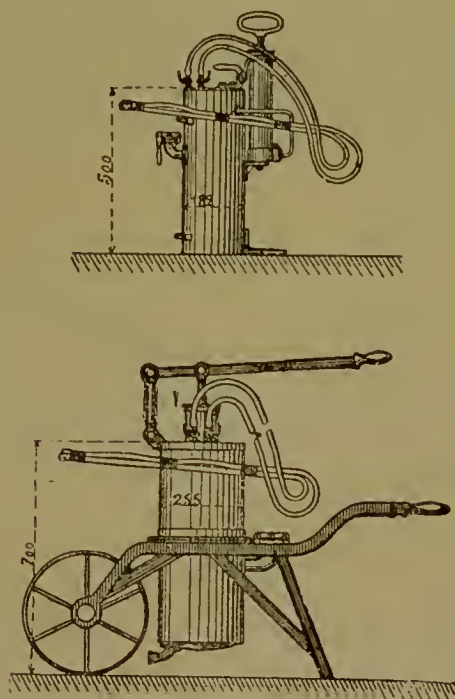
The application of liquid disinfectants to the walls and contents of the room referred to in the above-quoted instructions may be much facilitated by the use of a spraying apparatus. This, however, must be specially constructed for the purpose, as many of the liquid disinfectants are corrosive to metals. One of the best appliances for this purpose is the Equifex disinfectant sprayer which is illustrated in figure 14. This machine is so arranged that the fineness of the spray can be regulated as desired, and the parts in contact with the disinfecting liquid are lined with ebonite so as to prevent corrosive action.

Perchloride of Mercury.—This powerful disinfectant is not mentioned in the instructions above quoted because of its extremely poisonous nature, which renders it dangerous for use by unskilled persons. It is, however, one of the most powerful germicides known, and is used as a solution for spraying or washing surfaces in the proportion of 1 part to 1000 of water. The following directions are given for making the solution :—Half an ounce of corrosive sublimate to 1 fluid ounce of hydrochloric acid, and 3 gallons of water. This forms a colourless liquid like water which is highly poisonous, so to prevent accidents it should always be coloured. Aniline blue or violet ink, are suitable for this purpose. As the liquid is corrosive to metals, it must be kept in glass or earthenware dishes. Walls and fittings should be washed in warm water to remove the mercury after the 12 hours' exposure. It is recommended that the men using it should wear a suit of overalls to prevent the chance of danger, and they must be careful to wash themselves thoroughly before meals.

Disinfection of Slaughterhouses.—It has been pointed out that slaughterhouses are particularly difficult to disinfect because of the large amount of albuminoid matter present. For this reason neither mercuric chloride nor carbolic acid are effective. Rideal recommends sulphate of copper as one of the most useful disinfectants for such places.

THE EQUIFEX DISINFECTANT SPRAYER

FIG. 14.



DESCRIPTION.— The drawings shew two forms of this apparatus. During the plague visitation in Sydney (1900), the general form shewn in the upper drawing was used and found handiest for manipulation within rooms. It was fitted with two small wheels or castors, which enabled it to be moved easily about ; and the pump was provided with a handle similar to that shewn in the lower drawing, that form being found to be much more powerful and less fatiguing to operate. With it a spray of any desired degree of fineness and up to three feet long was found to be readily produced. The parts exposed to contact with the liquid disinfectant are made of non-corrodible material.

Disinfection of Rags.—In the United States, rags to be used for paper making must be disinfected prior to shipment, either by boiling, exposure to steam or to sulphurous acid. It is well known that rags often convey disease, and when they are packed tightly in bales they are difficult to disinfect. Methods have been introduced of forcing hollow screws into the bales, and so passing disinfectants into the centre of the mass, and also, driving in conical tubes, in order to facilitate their disinfection by steam.

CHAPTER VIII.

AIR.

Air is essential to man's existence, and as man lives in air, and the air continually flows into his blood, it is no wonder that he is influenced by the condition of the air. Pure air is a mechanical mixture of 209 parts of oxygen and 791 parts of nitrogen. The more important of these two gases is oxygen, and the nitrogen merely dilutes it, so that it may be rendered powerless to produce the evil results which follow when the pure gas is breathed; but the fact of the oxygen being so diluted does not in any way impair its power to oxidise the matters presented to it in the blood. The quantity of air actually inhaled and exhaled by an adult in 24 hours amounts on an average to about 360 cubic feet, or 2000 gallons. What we take in and what we give out during 24 hours in the shape of solid and liquid food, occupies on an average the space of $5\frac{1}{2}$ pints, which is equal to $\frac{1}{3000}$ of the volume of air passing through our lungs. This volume of air, which passes daily through the lungs, weighs about 25lbs. avoirdupois. Plant life furnishes back to the atmosphere the oxygen which animal life takes away from it, and it is in this way that the composition of the atmosphere is kept practically constant and universal. Although this composition is of a fairly constant nature, yet its actual percentage is not entirely uniform. The exigencies of life, the exhalations coming from the bodies of man and animals, the contamination due to the various trade processes, and combustion, all tend to produce gases and impurities, which become uniformly distributed in atmospheric space. Air mixed with other gases or holding in suspension organic or inorganic substances, is con-

sidered impure. Air in towns is never pure, and contains ammonia, carbonic acid, and suspended matters. The average composition of the atmosphere may be taken as follows:—Nitrogen, 771·2694 volumes per 1000 parts; oxygen, 206·5940 volumes; aqueous vapour, 14·00 volumes; argon, 77·96 volumes; carbon dioxide, 0·3360 volumes; ammonia, 0·0080 volumes; ozone, 0·0015 volumes; nitric acid, 0·0005 volumes.

Air on the sea coast also contains chlorides, and in this way differs from air found inland. It is upon the presence of the various subsidiary matters in air that greater or less degree of effect of air upon health depends. The gaseous impurities of the air are chiefly carbonic acid, carbonic oxide, carburetted hydrogen, and sulphuretted hydrogen. The chief impurity of the air is carbonic acid, and as this gas bears a fairly constant relation to the purity of the atmosphere, it is usual to measure the impurity of the air by the quantity of carbonic acid contained. By the action of breathing and transpiring the oxygen of the air is diminished, the carbonic acid is increased, a large amount of watery vapour is added, there is a large evolution of ammonia, and organic matter (in animals marsh gas), and a large amount of suspended matter is set free. Respiration is merely combustion, through which process a number of carbon compounds, or waste products of the living body are, in the blood, converted by oxidation into carbonic anhydride and water, which are finally given out by the breath. Through the process of respiration the oxygen of the air is diminished in the direct ratio of the carbon and hydrogen consumed in the system. The average adult gives off about ·6 cubic foot, or 17 litres of carbonic acid per hour, and inhales about 17 cubic feet of air in same time. Expired air contains about 45 per cent. of carbonic acid, or 4 per cent. more carbonic acid, and about 5 per cent. less oxygen than air which is inhaled. Air should be considered unfit for respiration when it contains more than ·06 per cent. of

carbonic acid, and consequently re-breathed air is dangerous to health.

The *Income* and *Expenditure* of matter during twenty-four hours of a man of average size and weight, and in a state of health :

INCOME.

OXYGEN taken in by lungs in respiration 11lb. 11ozs. 0grs.

FOOD —

Albuminous matter	...	...	0	4	0	
Fat	..	...	...	0	3	0
Starch or sugar (carbohydrates)	0	10	0			
Salts	...	...	...	0	1	0
Water	...	...	...	7	4	0
				<hr/>		
				10lb.	9	0

EXPENDITURE.

LUNGS— lbs. ozs. grs.

Water	...	...	...	0	10	6
Carbonic acid	...	...	...	2	0	0

SKIN—

Water in sweat	...	...	1	8	0
Vapour	...	...	0	3	2
Carbonic acid	...	...	0	0	60
Salts	(Too small to be stated)				
Nitrogenous matter	„	„			

KIDNEYS—

Water	...	...	...	4	0	0
Urea	...	...	...	0	1	20
Uric acid	...	..	...	0	0	7
Hippuric acid	...	...	...	0	0	6

EXPENDITURE—CONTINUED.

KIDNEYS (*Continued*)—

			lbs.	ozs.	grs.
Creatin ...	...	...	0	0	13
Pigment ...	...	...	0	0	150
Sulphuric acid ...	...	...	0	0	30
Phosphoric acid ...	...	...	0	0	45
Chlorine ...	...	...	0	0	105
Ammonia ...	...	...	0	0	10
Potassium ...	...	...	0	0	30
Sodium ...	...	...	0	0	165
Magnesium ...	...	...	0	0	3

BOWELS AND LIVER—

Water ...	...	...	0	4	0
Salts ...	...	...	0	0	90
Nitrogenous matter and refuse			0	1	90

Total ...	...	...	9	4	342
Organism has gained		...	1	4	135

10 9 0

A healthy adult man, therefore, introduces into his body in 24 hours about 11 lbs. troy weight of matter, and loses during the same period 10 ozs. water, 2 lbs. carbonic acid by the lungs, 2 lbs. of matter by the skin, $4\frac{1}{2}$ lbs. of water, nitrogenous matter and salts by the kidneys, and about 6 or 8 ozs. by the bowels. The nitrogen in the atmosphere, as said before, acts as a diluent of oxygen, reducing its strength and rapidity, and supplies plants with a certain amount of nourishment which is washed down out of the air into the soil after the rain. The oxygen, although only $\frac{1}{5}$ of the volume of the atmosphere, is the most important element which enters into its constitution, and maintains every kind of life. Its modification *ozone* is an important factor in the purification of air. As before mentioned, it is by the amount of carbon dioxide or carbonic acid in the air that impurity of air is measured. The chief sources of this gas in the

air of rooms—are in respiration, and combustion. The impurities given off by fires and artificial lights tend to impair the healthful properties of pure air. Coal requires at least 240 cubic feet of air for the complete combustion of every pound. During the combustion of coal, about 1 per cent. is given off into the air as soot and tarry products, with other impurities. For every ton of coal burnt three tons of carbonic acid are produced. Wood produces on combustion carbon dioxide and carbon monoxide, but less sulphur compounds than coal does. “The blue flames so often seen at the top of a well-drawing fire, consist of burning carbon monoxide.” Those forms of artificial lighting which render air impure are candles, oil, and coal gas. A candle on complete combustion yields .41 cubic foot of carbonic acid to the air, and an oil lamp gives .28 cubic foot of carbonic acid per hour or more. Combustion, therefore, gives off gaseous products which are rapidly diffused by air, and an important cause of the impurity in the air in town houses arises from the use of coal gas. The products of the combustion of coal gas vary much with the quality of the gas used, and the completeness of the process. One hundred cubic feet of coal gas will consume the oxygen in, or destroy the vital qualities of 800 cubic feet of air, and each cubic foot of gas burned per hour, may be assumed on an average to vitiate as much air as would be rendered impure by the respiration of one individual. The products of the combustion of coal gas are—carbonic acid, carbonic oxide (with incomplete combustion), compounds of sulphur, and ammonia. An ordinary gas-burner, with an open flame, in practice consumes from 6 to 9 cubic feet per hour, so that it would consume as much air as 6 or 9 men would, and gives off 3 cubic feet of carbonic acid, 9 cubic feet of watery vapour, and 3 grains of sulphuric acid. The result of combustion of coal gas is to illuminate and give heat, but it renders the air impure. The incandescent gas-burner, as patented by Welsbach, consists of a network of

oxides of rare earths heated to incandescence by means of a Bunsen burner. As shewn by a report published in the *Lancet*, Jan. 5, 1895: "The Welsbach burner affects the atmosphere far less for evil, judging from the carbonic acid and heat produced, than any other existing type of coal gas burner." Air may contain from '03 to 1 milligram of ammonia per cubic centimetre, and the variations of the amount of this impurity are upon the whole parallel with those of carbonic acid, and are similarly influenced by meteorological changes. The quantity of watery vapour or moisture in air varies greatly in different countries. In wholesome air it should not be less than 40 per cent. or more than 75 per cent. Air contains such suspended impurities as—seeds of plants, spores of fungi, bacteria and dust (organic and inorganic); and as a rule this suspended matter is of an innocent nature. "When air, under constant pressure, is heated it expands according to a definite law (Charles), which is, that for each degree of temperature added to its heat, it expands a certain constant fraction of its own volume, this fraction being known as the coefficient of expansion." By Boyle's law—under varying conditions of pressure, but a constant temperature—"the volume of gas is inversely proportionate to the pressure." Therefore, according to these two laws, for any volume V , at any pressure p , and at any temperature t° , the weight w will be

$$w = \frac{1.293 \times V \times p}{760 (1 + (0.003667 \times t))}.$$

Gases are readily diffusible, and, according to the law of Graham, they diffuse "inversely, as the square roots of their densities." "It is this diffusion of gases which conduces so largely to the composition of air being kept constant, and which enables the carbon dioxide so freely formed in our large towns and cities, by combustion and respiration, to be rapidly removed from where it is formed to other parts, where the processes of vegetation and sunlight can break it up.

into carbon for the food of plant life and oxygen for the use of men." The poisonous qualities of respiratory impurities are mainly, if not entirely, due to the organic matter contained in the respired air; and these substances are in open country continually dispersed into the surrounding atmosphere by atmospheric currents. In dwellings and confined spaces, however, there is no such opportunity of dispersal, and as expired air contains much organic matter, it promotes the growth of organisms, so that milk, meat, or other food, which may be brought into contact with such air, become quickly tainted. In all inhabited rooms, especially if they are not well ventilated, there is an enormous increase of bacteria. Carnelly, Haldane, and Anderson found that when the *moulds* and *bacteria* in the external air were as—2 to 6, in houses of four rooms and upwards they were 4 to 85; in two-roomed houses, as 22 to 430, and in one-roomed houses as 12 to 580. In *sick rooms* the air is vitiated by respiration, and is contaminated by the abundant exhalations from the bodies of the inmates, and by the effluvia from discharged excretions. Ransome and Cornet have demonstrated that the bacilli of tuberculosis attach themselves to particular small localities, and are to be found in the air and dust, and on the walls of rooms which have sheltered phthisical patients.

The Air of Workshops and Factories is rendered impure by the various trade processes, and *offensive gases from trades* are frequently to be found polluting the air, and lessening the oxygen of the atmospheric air.

The *Air in Mines* is, says Angus Smith, poor in oxygen and very rich in carbon, and its impurities result through respiration, combustion, and explosives. These latter substances add to the air in addition to carbonic acid, carbonic oxide, hydrogen and hydrogen sulphide. Through the investigations of Nasmyth we are informed that the air of coal

mines contains carbon dioxide 1·81 per 1000 when the mine is moderately deep; 2·19 per 1000 when the mine is over 100 fathoms. The presence of men and horses in mines more directly determines the growth of micro-organisms than even stagnation of air and high temperature. There are no great vicissitudes of temperatures in mines. Black damp consists, according to Haldane, of nitrogen containing $\frac{1}{7}$ of its volume of carbonic acid; it is not explosive, but, on the contrary, extinguishes fire. Black damp is the residual gas left on slow oxidation of the carbon and hydrogen of coal by air. Air may be polluted by *sewer emanations* which lessen the amount of oxygen in the atmosphere. Sewer gas has no settled composition, and the air in well-ventilated sewers differs little, if any, from the air outside. As a rule, sewage decomposes into fœtid organic matter, carboammoniacal substances, carbonic acid, nitrogen, and hydrogen sulphide; the gases being in variable proportion, and of less importance than the fœtid organic matters. These organic matters cause a peculiar fœtid smell, and 8000 cubic feet of the air of a house into which sewer air had penetrated destroyed more than twenty times as much permanganate potash as the same quantity of pure air (Angus Smith). Haldane has demonstrated that fewer germs are found in the air of a sewer than are found after shaking a doormat, and that the micro-organisms present are derived from the outside air, and not from the sewage itself.

Impurities from Respiration.—Expired air contains fully a hundred times more carbonic acid, and nearly five per cent. less oxygen than the atmospheric air.

	Ordinary Air.	Expired Air.
Oxygen	20·96	16·40
Nitrogen	79·00	79·19
Carbonic Acid ...	0·04	4·41

The diminution in volume of respired air is compensated by the warming of the inspired air in the

air passages, so that eventually the volume of expired air is $\frac{1}{9}$ greater than the air inspired. If carbonic acid is present in air, in any proportion over .6 per thousand, it indicates that there is an amount of injurious organic impurity present, but the carbonic acid itself does not begin to be injurious till it reaches 15 per thousand. No conclusion can be drawn from the number of bacteria present in the air of enclosed spaces, as they depend upon habitual cleanliness and ventilation. The number is smallest after a heavy fall of rain or snow, and very markedly increased during a dry wind. As a rule, these microbes adhere to moist surfaces, but may be given off from the bubbles bursting on the surface of stagnant and putrefying matter. Microbes in the air vary in number according to the locality, season, time of day, and meteorological conditions. Angus Smith states—"The germs which induce putrefaction are ubiquitous. The air we breathe, all that we eat and drink, and touch and lie on, keep us continually exposed to the reception of germs." As the variety of species of micro-organisms is enormous, the atmosphere is ordinarily loaded with a large number of forms, some of which may be of a pathogenic nature. There is no definite connection between the number of microbes in the air, and the amount of carbonic acid, further than that, in general, if the proportion of carbonic acid is high, it is usually accompanied by a high proportion of organic matter. Bergey, Weir Mitchell, and Billings, believe that the discomfort of crowded and ill-ventilated rooms, to persons not accustomed to them, is due to excessive temperature and unpleasant odours, which are the products of decomposition contained in the expired air of persons having decayed teeth, foul mouths, and certain disorders of the digestive apparatus. *Dust*, which mainly consists of mineral particles, may and does frequently contaminate the air by being a *vehicle* for conveying matters which *will* contaminate it and prove injurious to health,

more especially as they may contain the germs of disease and irritant matters. On wood-paved streets it has been found that the mud consists almost entirely of horsedung, which may, according to Klein, contain germs which give rise to epidemic diarrhœa. Ramazzini, in the last century, and Thackerah more than fifty years ago, showed that the effect of dust of different kinds in the air is a potent cause of respiratory infection. The effluvia of some flowers, and the dust of others, may cause disease, and specific poisons may float through the atmosphere on, as it were, rafts of dust particles. Air may be contaminated by trade processes, and this contamination may effect both the lungs and the digestive organs. The severity of the effects of the inhalation of suspended matters is chiefly dependent upon the amount of dust and on the physical conditions of the particles. The pathology of the morbid changes caused in mines is that of a slowly generated fibrosis of the lungs. Grinders, miners, linen workers, tailors, hairdressers, masons, plasterers, etc., are subject to diseases of the lungs. Brass founders suffer from ague, painters and plumbers from lead poisoning. Mercurial fumes are injurious, as also are the fumes given off in working a linotype machine. Brick-making, match-making, copper smelting, all give rise to disease. Artificial flower-makers suffer from slight symptoms of arsenical poisoning.

Gases and other gaseous emanations, have an indefinite and discursive influence upon health. Of the immense effect of carbon monoxide there is no doubt. Less than 3 vols per 1000 have produced poisonous symptoms, and more than 10 per 1000 are rapidly fatal to animals.

"It appears that the gas, volume for volume, completely replaces the oxygen in the blood, and cannot be *displaced* by oxygen, so that the person dies, asphyxiated; but Pokrowsky has shown that it may be gradually converted into carbonic acid, and got rid of." (Lane Notter.) It is an inodorous,

unirritating gas, which produces its poisonous effects insidiously, the early symptoms being loss of the power of movement. It generally arises through imperfect combustion, and forms a blood poison, through which a rapid parenchymatous degeneration of the heart, muscles, liver, spleen, and kidneys takes place.

Sulphuretted Hydrogen.—When inhaled in small quantities has no bad effects, but in larger quantities it proves fatal, and sets up the symptoms of weakness, depression, anorexia, slow pulse, furred tongue, with nausea, headache, diarrhœa, and head symptoms. In kiln burning of bricks, acid, irritating, and injurious effluvia is given off, which consists of certain pyroligneous matter, in addition to the ordinary gases of combustion. Most of the multifarious trades concerned with animal products are liable to cause effluvia, and such effluvia often constitutes a grave nuisance, which becomes the source of disease. An undue proportion of carbonic acid in the air may kill outright; but when organic matter is present in the air, it renders the air impure, and to it, diseases of impure air are mainly traceable. Although these industrial gases frequently constitute a nuisance, it is often difficult to prove that they are not salubrious. Instances of mephitic poisoning, through sewer emanations, have frequently occurred, and the constant breathing of air polluted by sewer emanations, induces an adynamic state of health, and lessens the refractoriness of the system to diseases such as diarrhœa, enteric fever, gastro-intestinal disturbance, sore throat, anæmia, cholera, pneumonia, and diphtheria. Such air, however, may not, and need not, contain the specific poison necessary to produce these several diseases, as the effect is to predispose to disease, rather than to produce the disease itself. It has been the experience in Sydney, New South Wales, as it has been that of observers in different parts of the world, that men working in well-ventilated sewers are not likely to suffer from

any ill effects, nor are they found to do so. As the necessity of observing cleanliness of the body is of paramount importance, with the health of the mind, so securing of pure air and pure water is absolutely essential to sanitation. The sudden changes from the hot, moist, impure air of work rooms to the external air, assisted by the inhalation of dust particles, raise the mortality from lung diseases. To keep the air pure it is necessary : (1) To determine the condition of the air ; (2) to remove all superfluous moisture ; (3) to collect, remove, and properly dispose of sewage, house garbage, and street refuse ; (4) to properly construct and scavenge streets ; (5) to prevent smoke ; (6) to prevent overcrowding of population on a given area ; (7) to provide and conserve open spaces in towns. In considering the conditions necessary to preserve air pure, or rather what standard of impurity in air is permissible, it is necessary to arrange that the air may be frequently changed without causing any inconvenient amount of draught. The comfort of ventilation depends on letting the air flow into a room at such a temperature, with such a velocity, and in such a position as will prevent the inmates feeling any sensation of cold or draught. Sometimes it appears as if draught is felt, but frequently the sensation arises through the result of loss of heat on one side by the radiation towards the adjacent cold surface. When air becomes impure, a carefully-educated sense of smell will detect the impurity, and will also afford a good indication of the relative purity and impurity of different kinds of air.

Air becomes devitalised through the organic impurities which diffuse themselves through it ; but the impurity of air only slowly makes itself evident, and as it may stagnate in different portions of the room or dwelling, care must be taken to prevent unequal ventilation, or people would practically live in a vitiated atmosphere. It is to be carefully noted that although the carbonic acid of expired air

DE CHAUMONT'S TABLES.

	Temperature.		Vapour.		Carbonic Acid per 1000 vols.	
	In Air Space.	Excess over Outer Air.	In Air Space.	Excess over Outer Air.	In room	Excess over Outer Air.
Fresh	62·85	5·38	4·629	0·344	0·5999	0·1830
A little smell..	62·85	8·00	4·823	0·687	0·8004	0·3894
Close or disagreeable smell ...	64·67	12·91	4·909	1·072	1·0027	0·6322
Very close, or offensive and oppressive smell ...	65·15	13·87	5·078	1·409	1·2335	0·8432
Extremely close, when the sense of smell can no longer differentiate ..	65·05	13·19	5·194	1·319	1·2818	0·8817

diffuses fairly readily, organic matter is less volatile, and hangs about in invisible clouds, unless dissipated by local currents. Out of doors, so long as air is in movement, the products of vegetable and animal waste are being continually removed by the air from the vicinity of their origin.

Examination of Air.—In taking a sample of air it should be taken at a time when there is a likelihood of the state of such air affording evidence of greatest pollution. Wide-mouthed stoppered jars, of three or four litres capacity, should be used, they should be thoroughly clean and dry. Full information should be given of current temperature and pressure, and locality, and environment of locality, from which the sample is taken. This sample may be taken in two ways:—

1. "The air may be blown in by bellows, which are provided with a long nozzle capable of reaching

to within an inch of the bottom of the jar. This insures that the air which originally filled the jar will be entirely displaced from below upwards."

2. "The jar may be accurately filled with distilled water, then inverted, emptied, and allowed to drain dry in the room, the air of which it is desired to collect; as the water flows out, some of the air rushes in to fill its place. Special care needs to be observed that no breath is introduced into the jar. The vessel is at once closed with an air-tight stopper or india-rubber cap, and the label inscribed with the current temperature, barometric pressure, and cubical capacity of the jar"

Examination by the Senses.—This is of first importance to detect, carbonic acid, carbonic oxide, marsh gas, minute quantities of organic effluvia, sulphuretted hydrogen, coal gas and carbon disulphide. De Chaumont, whose tables have been already given, was the first person to clearly show the value of the sense of smell, especially on first entering a room from the open air. Atmospheric humidity has a marked influence in rendering the smell of organic matter perceptible, and "as the sense of smell soon becomes blunted, it is important, when attempting any examination of the air by the senses, to record the impression received, immediately after entering the suspected or vitiated air from the open, and not to delay it until one has been in the apartment some length of time."

Reaction of an air sample, whether acid or alkaline should be noted by litmus or turmeric papers, change or not in colour shew the presence or absence of ammonia or sulphurous acid.

The Estimation of Oxygen in the Air is determined by three methods, of which one, the nitric oxide process is the most readily applicable. This process is complicated, and the reader is referred to larger works than this for a full description of both the method and the apparatus which is known as Hempel's gas burette and absorption pipette.

The Amount of Carbon Dioxide.—Carbonic Acid in the air is determined by Pettenkofer's Alkalimetric method :—

Clear lime water will readily absorb carbonic acid, and the absorption of this weak acid will diminish the alkalinity or causticity of the original lime water. If, therefore, the degree of alkalinity of the lime water is known both before and after the exposure to the carbon dioxide the difference will represent the amount of carbonic acid which has combined with the lime. The causticity of lime water is determined by titration with a solution of crystallised oxalic acid (2.25 grammes in a litre of distilled water). Cohen and Appleyard estimate the carbon dioxide in air by shaking with the air sample, dilute lime water coloured with rosolic acid. The time required to decolorise the indicator will give the quantity of carbonic acid present. O. Schulz draws air, by means of an aspirator, through a measured quantity of standard carbonate of soda solution coloured with rosolic acid, placed in a long test tube. When the colour is discharged, it indicates that neutralization has been effected by the carbonic acid in the quantity of air drawn through. The amount of carbonic acid can then be calculated according to the strength of the soda solution.

The Determination of the Organic Matter in the air is obtained by washing the air by agitation in distilled water, and then estimating the nitrogen, the free and albuminoid ammonia, as well as the nitrous and nitric acid as described in the methods of water analysis. In this way the amount of nitrogenous matter is estimated. The oxidisable matters are estimated in terms of oxygen by drawing a definite quantity of air through a solution of permanganate of potash of known strength, and the amount of undecomposed permanganate is determined by sodium thiosulphate. Some difficulty may be experienced in matching the tints, and in some samples no amount of permanganate will bring the decolorised sample up to the standard colour, and it must be remembered

that permanganate acts upon various matters in the air besides the putrescible organic matters.

There is no easy test for the *estimation* of that dangerous gas, *carbon monoxide*. Vogel adds to a sample of air a drop or two of blood from a pricked finger, and shakes the mixture well before examining a small quantity of it in the spectroscope, for the absorption bands, all of which is thoroughly explained in larger text books. There is also another test by noting the volume of air absorbed by sub-chloride of copper.

Ozone is determined by the action of air upon faintly reddened litmus paper moistened with potassium dioxide. The ozone turns the paper blue.

Sulphuretted hydrogen may be detected by exposing paper moistened with lead acetate in the air. The paper becomes black through the formation of sulphide of lead.

Pouchet's aeroscope, and Marie Dewy's modification of it, are used in the *Examination of suspended matter and micro-organisms*. The principle of this apparatus is allowing a fine current of air to impinge upon a circular glass plate previously smeared with glycerine. Many other methods have been used, but the simplest, and a very trustworthy one, is the filtration of air through cotton wool. Hansen has also found that a dry Pasteur-Chamberland tube frees the air from organisms as long as the tube is dry. For the thorough bacteriological examination of air, the Hesse method, described at length in larger text books, is the most satisfactory.

Ventilation. — Ventilation may be defined, as the provision of arrangements, whereby the air necessary for the healthy existence of man, and the lower animals, may be provided, particularly within enclosed or confined spaces. This involves the provision, not only of a certain *quantity*, but of a *quality*, in relation to purity, moisture, and temperature, such as will constitute, not only healthful, but also comfortable, conditions. An element of difficulty is also intro-

duced into the problem in the very varied ideas held by different people as to what they consider a desirable warmth and freshness in their surroundings. These varied requirements render the designing of ventilating arrangements for large public places of assembly, a matter of very great difficulty, calling for a thorough training in physics, and a wide practical experience. The problem, in the case of ordinary dwellings, is, however, a much simpler matter, and as these will furnish the bulk of the cases calling for attention from the sanitary inspector, the work is rendered much easier in his case.

Ventilation Methods. — Just as a chimney, however tall, can have no draught through it, unless it has an opening at the bottom as well as the top, so there can be no ventilation in an enclosed space without the provision of *inlet* openings as well as *outlet*. This is a point often forgotten, and people will indicate an opening in the ceiling as providing sufficient ventilation. If the conditions of atmosphere and temperature are such as to induce a current through such an opening, then, if no properly placed inlet be provided, the practical effect of it would be to produce a suction, or partial vacuum, in the room, which would cause every crack or cranny in the enclosing house-fittings to become an inlet. Such openings are mostly to be found under doors, and around ill-fitting windows, particularly the former, and, especially in cool weather, violent draughts of cold air sweep along the floor, giving rise to great discomfort in the form of cold feet. This is especially noticeable in the case of rooms having an open fire, which, with its heated chimney, forms a most powerful outlet opening for ventilation, and so greatly increases the discomfort, by accentuating these cold draughts, which, in this case, pass directly from all such accidental openings to the fire, so exposing those sitting around it to what is really a chilling wind, playing on their legs and back. The moral of all this, of course, is, the necessity for properly

proportioned and properly placed air inlets. In order to understand the guiding principles applicable to this matter, it is necessary to know about the influence of heat as affecting the motion of air, because, in all ordinary cases, it is the difference in temperature between the air inside and outside of the house, which furnishes the motive power, without which the motion of the air necessary for ventilation would be impossible.

Motion of Air due to Temperature.—Almost every one realises that a chimney containing warmed air will have an upward draught, and most people have, by sad experience, learned that, house chimneys at all events, sometimes under certain conditions, develop a persistent down draught. To the ordinary unthinking public, the reason of these contradictory currents is as mysterious as an ordinary gas meter, but the explanation is very simple when understood. Everyone knows that a cork will rise through water, because, as the popular saying is, it is lighter than water; this means that, bulk for bulk, the cork weighs considerably less than water does. Iron, on the contrary, sinks in water, because, bulk for bulk, it is heavier. Now, the motion of air in relation to temperature is due to precisely similar causes, but the difference in weight is produced by change of temperature, which causes expansion or contraction, as the case may be. This, of course, has the effect of rendering a given bulk of the air lighter, or heavier, as it is heated and expanded, or cooled and contracted. In other words, heated air, in the midst of cool air—as for instance, warmed air in a chimney surrounded by cooler air—rises, just as the lighter cork rises through the heavier water. Cooled air in the midst of warm air, on the contrary, descends, just as, and for the same reason, that the heavier iron sinks through the lighter water.

Now, while we find among people of average education, a realisation that the *heating* leads to the ascending currents, both in the case of water and of

air, there are singularly few who realise that cold, or cooling, produces the opposite effect in both cases, and further that the same *difference* between the temperatures of the masses of water, or of air, will produce the same vigour or speed in the descending current, due to cold, as in the ascending current, due to heat. It is the lack of understanding this fact which leads to many failures in ventilation arrangements; failures which are the more to be regretted, in the smaller class of houses, because in hundreds of cases the discomfort so arising, leads to the stopping up of ventilation openings, and the rendering useless of arrangements, which only require to be intelligently used to be effective, without discomfort.

This influence of temperature on the motion of air, is, therefore, of the first importance to the Sanitary Inspector, and the whole matter is so simple, that it may be summed up in a few words. It is sufficiently near, for our purpose, to remember that air expands in bulk or contracts about one part in every 491 parts for every degree of Fah. it is heated or cooled. If then, we heat air to 491deg. from zero, which is by no means an exceptionally high temperature (being but little over that of a baker's oven), we expand it 491 parts in 491 parts. That is to say we double its bulk. If, then, one cubic foot of air at zero becomes two cubic feet at 491deg., clearly each cubic foot at the latter temperature, can be only half the weight of that of the former. People generally do not realise that air has weight, because they cannot pick it up and feel the weight of it, as they could a piece of stone, or a bucketful of water. But the student even of elementary physics knows that air has weight; and if we think for a moment, we shall realise that the sometimes very great pressure against our bodies of a gale of wind, is due to its weight dashed against us with greater or less velocity, according to what we call the strength of the wind, just as the pressure of a stream of water is due to its weight multiplied by its velocity. Further, that a wind pressure or

current will exert a power due to its weight, and its velocity, which will carry light articles along with it, what we call a hurricane, even moving heavy stones, logs of wood, and other ponderous articles, just in the same way, and for the same reason that a torrent of water does. In point of fact, 13·14 cubic feet of air at 62deg. Fah. weighs one pound, and is so $\frac{1}{819}$ th part of the weight of water. If now, therefore, we take a vertical pipe measuring 1 foot square, clearly if it is 13·14 feet high, it will contain air weighing 1lb., provided the temperature is 62deg. Fah. If the surrounding air is also at 62deg. Fah., clearly the mass of air contained in the tube will have exactly the same weight, bulk for bulk. It follows that this contained air will neither have a tendency to rise or fall through the surrounding air, but will remain stationary. In other words, under such circumstances, there will be no motion, or draught, in the vertical pipe or chimney. If now we take means to heat the air in the chimney, and so raise its temperature by 491 deg., that is to say, to 62 + 491, or 553deg. Fah., we will, as we have seen, double its bulk. In other words, our column of air in the tube would require that tube to be extended to a length of 13·14 x 2 or 26·28 feet, in order to contain it; that is, the height of the top of the column contained in the chimney would be 13·14 feet above what it was at 62deg. This difference constitutes what, for the purpose of calculating the velocity of the current, is called the head of air. Now, it is obvious that if the 13·14 feet high pipe contains 1 lb. of air originally, the mere expansion of that air cannot alter its weight; hence, it follows that the 26·28 feet high column of heated air also weighs only 1 lb., so that clearly the half or original height can, when heated to 553d g., weigh only half of a lb. In other words, if we heated the original lb. of air to 553deg. without lengthening the chimney, the expansion would have the effect of pushing half of the weight of air out of the chimney.

thus leaving the contained air remaining, only half of the weight of the air surrounding it. Here, then, we have at once established the conditions similar to the lighter cork surrounded by the heavier water, and the lighter air similarly ascends rapidly through the heavier surrounding air, so producing a vigorous up-draught in the chimney. Now, if the air had been cooled 491deg. from 60 – that is to say, to 431deg. below zero—instead of heated, it would so be contracted presumably to half its bulk. Assuming that this is an accurate statement, clearly, bulk for bulk, the air would be doubled in weight— that is, the air in our 13·14 feet chimney, if at 431deg. below zero, would weigh 2 lbs. It is, therefore, bulk for bulk, twice as heavy as the air surrounding it, and, like the heavier iron in the lighter water, it descends or sinks, so producing a descending current or draught in the chimney, which would be equal in vigour, that is to say, in velocity, to the ascending one, due to the equivalent *rise* in temperature.

Rule for Velocity of Motion.—The rules for the motion of bodies due to differences of weight for equal bulks, is based on what is called the law of falling bodies. That particular form of the formula in which the motion of falling bodies is expressed, and which is of use in this connection, is $V = 8\sqrt{H}$:— When V is velocity in feet per second, and H is the height in feet, the body has to fall, or, as it is called when applied to the motion of air or water, “Head.” This means that, for instance, in the case of a stone falling through the air, the square root of the distance (H) it has fallen, multiplied by 8, gives the velocity in feet per second with which it is moving at that point.

In the case of air, the height H is represented by the height to which the column of air is expanded (at the temperature attained) above its height at the temperature of the surrounding air. Thus, taking the case already quoted of our 13·14-foot chimney,

the formula for ascertaining H , when due to heating, may be stated as follows :—

$$H = \frac{(t' - t) \times h}{491} ;$$

491

when t is the temperature of the outer air
 t' is the temperature of the air in shaft,
 (or in room in some cases), and h is the height in feet of
 the chimney or air shaft. The quantity H being thus
 ascertained, the velocity may be calculated from the
 formula already given, viz : $V = 8\sqrt{H}$. It should be
 noticed that this gives the theoretical velocity or
 speed of the moving air, but a deduction must be
 made for the friction in the flue or shaft. This
 depends on size, shape, and smoothness of the shaft,
 and also varies inversely with the square of the
 velocity. The formulae required for calculation of the
 retardation of the current due to these causes, are

QUANTITY OF AIR EXTRACTED PER MINUTE BY
 VENTILATING SHAFTS HAVING A SECTIONAL
 AREA OF ONE SQUARE FOOT OR 144 SQUARE
 INCHES.

Height of Ventilating Shaft in feet.	Excess of Temperature of Air Entering the Ventilating Shaft above the External Air.					
	5°.	10°.	15°.	20°.	25°.	30°.
10	116	164	200	235	260	284
15	142	202	245	284	318	348
20	164	232	285	330	368	404
25	184	260	318	368	410	450
30	201	284	347	403	450	493
35	218	306	376	436	486	531
40	235	329	403	465	518	570
45	248	348	427	493	551	605
50	260	367	450	518	579	635

rather difficult of application, and in practice an allowance of 25 per cent is often made. That is to

say, that only three-fourths of the velocity obtained by the above formula is taken. Hood gives the foregoing table, which will furnish a useful guide to Sanitary Inspectors.

It should be remembered in these cases, that, as the velocity is due to the temperature *throughout* the shaft, over or under that of the outer air, any loss or gain of heat through the sides of the shaft, will, of course, reduce this difference in temperature, and so reduce the velocity of the current through it. For this reason, any good conductor of heat, such as sheet-iron, is not a desirable material, unless it is coated with some good non-conducting substances, such as wood or felt.

All such flues should also be so designed as to give the largest sectional area for the smallest perimeter in the enclosing sides. The notes given on page 92, as regards this, will be found useful. From these it will be seen that in practice the circular or square section is best, and oblong or irregular sections are to be avoided when possible. Another fruitful cause of obstruction to air currents is to be found in sharp angular bends. It has been estimated that every right-angle bend in an ordinary ventilating shaft, will reduce the current by one-fourth. This is, of course, an empirical rule, and the actual loss would vary very greatly under different conditions of velocity, and shape and size of flue, but the loss is sufficiently great to demand easy curves, having a radius of not less than five diameters of the shaft, whenever change of direction is absolutely required.

Distribution of Air.—The equable distribution of the incoming air throughout the *whole* enclosed space, is one of the most important, and it may be added, one of the most difficult, points in ventilating arrangements of all kinds. In this connection, the behaviour of currents of cooler air, entering a mass of air at a higher temperature, and of warm currents entering a cooler space, furnishes the key to the whole matter. Here again, the behaviour of water jets passing

through air, will furnish us with a visible example of what takes place invisibly in such cases.

If we observe the behaviour of a strong jet of water thrown upward into the air, such as the jet from a fire hose, or a fountain, it will be noticed that almost from the moment the water leaves the nozzle, it begins to spread and break more or less into spray, and when it attains its maximum altitude and begins to fall, it is already partly broken up into drops. These drops divide up still further as they fall through the air, and, if the fall is great enough, the whole mass of water becomes spread out into a fine spray, resembling the finest drizzle of rain. In very high waterfalls, when the volume of water is small, and it falls freely through the air, the same effect is observed. This action is due to the friction of the air against, 1st, the sides of the solid jet; and, 2nd, against the large individual drops, when the water is broken up to that extent. Now, the same action precisely takes place, though invisibly, in an air jet driven into a mass of surrounding air, but the air is much more quickly broken up in air, than is water in air. Further, as we have seen, the influence of heat or cold may cause the air current due to it, either to ascend or descend. Therefore, in the case of air, a hot air current *ascending* through a mass of cooler air, will be broken up into what might be called, a fine air spray, just as the falling water is. A current of cooler air descending through a mass of warmer air is also broken up in the same way. The conditions, therefore, required to effect this action, are, a sufficiently *thin* air current, so as to secure a large surface exposed to the surrounding mass of air in proportion to its sectional area, and a sufficient length of travel to enable the friction of the surrounding air to do its work of breaking up thoroughly. Applying this to our entering air currents, the following rules become apparent:—1st. Warmed air entering a cooler room should be admitted at the *lower* part of the room, and should be directed

downwards and *inwards* towards the centre of the air space to be ventilated. 2nd. Cool air entering a warmer room should be admitted some distance *up* from the floor, and should be directed *upwards* and also *outwards* towards the ceiling, and the centre of the section of the space to be ventilated by it.

Cold Draughts.—In ventilating arrangements, particularly in the smaller class of houses, the cause which, as already stated, leads to ventilation openings being stopped up by the inmates, and so of course rendered inefficient, is almost in every case the discomfort, and perhaps even illness, caused by cold draughts proceeding from them. It is, therefore, desirable clearly to understand the real cause of such draughts. If the principles above enumerated are attended to, there need be no cold draughts, because for ordinary houses, given the proper placing of openings, particularly inlets, the proper direction (upwards or downwards, as the case may be) given to the entering air, and the division of the incoming current into a sufficiently thin stream or streams, the cooler air will be so broken up and mingled with the warmer air of the house, that no draught will be felt. This will be due partly to the thorough mixing of the air, without which proper ventilation is impossible, and partly to the reduction of the velocity of the moving air due to its spreading among, and consequent friction with, the general body of air in the apartment. The sensation of cold draughts, or unpleasantly burning currents of hot air is produced, by the transference of the heat from, or to our bodies, by its contact with the body, and also by the cooling effect of evaporation, which is ruled mainly by the condition of the air as to moisture or dryness, but is also influenced by the current. This last is easily realised by the every-day action of fanning. In this, air which is so moist, and warm in temperature as to render it actually muggy, and so apparently oppressive to our senses, is yet made to induce a sensation of coolness by the operation of fanning. That is to say,

by simply putting this same air in motion its evaporating, and consequently cooling effect, is so increased, that it seems to be cold. The electric fans and the old-fashioned punkah simply act in this same way. We have thus two influences always at work. First, transference of heat by contact of the air with our bodies, which, when the air is lower in temperature than our bodies causes transference of heat from our bodies to the air, so producing the sensation of coolness or cold, according to the degree of difference in temperature, and when the air is higher in temperature than our bodies, a similarly strong sensation of warmth or burning heat as the case may be. Second, transference of heat from our bodies to the air by way of the vaporized moisture from the perspiration, producing the sensation of coolness or extreme cold according to the dryness of the air and consequent speed of evaporation.

The power of both of these factors is greatly increased when the air is in motion and the quicker the speed, the greater the increase in power. For example, the life-destroying cold of the dreaded blizzard of North America, is due to the greatly increased power of the cooling effect, of already low temperatures, and dry air, conferred upon it by the creation of rapid currents due to gales of wind. At the other extreme, Mr. J. L. Bruce has found that, while dry air is still, a temperature of over 300 deg. F. is perfectly endurable without discomfort, but a current of even from 3 to 4 feet per second renders those conditions unendurable for more than a minute, because of their scorching effect on the exposed portion of the skin. It thus appears, that with a low temperature, and dry air, we have a very rapid abstraction of heat from our bodies, both by contact of air and by evaporation. With air dry, but warmer than our bodies, we have loss of heat by evaporation, but gain from contact with air, and with air dry, but at high temperatures we have the same give-and-take action. With dry air extremely cold, or extremely

hot, we have endurable conditions, provided the air is still; but with air in motion at even 3 to 4 feet per second these conditions become unendurable. With air charged with moisture, the ranging of temperature up and down, which is comfortable, becomes very much reduced. Thus, Galton has pointed out, that with saturated air, temperatures between 50 and 65 degs. are comfortable; below 50deg. they become increasingly and unendurably chilly; above 65deg. they become muggy and most oppressive, and, he adds, it is doubtful if life could be prolonged in a saturated atmosphere of 90 to 100 degs. Fah. Here then we have a collection of facts bearing closely on the question of draughts. The matter is crudely stated in some text books to the effect that an entering current of more than 3 feet per second (some say 4, others 5) will produce a sensation of cold draught. This method of stating the matter is most misleading, for, in the first place, a current of much *less* than 3 feet per second will produce a sensible cold or hot draught, if the differences above referred to, be sufficiently great, and a current of considerably *more* than 5 feet per second will not do so, provided these differences are slight or non-existent. In the second place the velocity of the entering current is a matter of not the slightest importance in this respect, provided that current is so directed that the *general* motion of the air, in that part of the room where its inhabitants are, does not exceed from 3 to 4 feet per second, under ordinary or average conditions of temperature and moisture.

Ventilating Appliances.—The names and design of the different ventilating appliances in the market is legion; some more or less useful; some represented as capable of doing what is known to be impossible, because contrary to physical laws. To attempt to describe this host, and separate the sheep from the goats, would be impossible, as well as needless. It often happens, that failure results from the notion, that the purchase and insertion of some well advertised appliance is all that is necessary, and

THE SANITARY INSPECTOR'S TEXT BOOK.

VENTILATING COWLS (INLET AND EXHAUST).
(Approved by the Sydney Board of Water Supply and Sewerage,
after exhaustive tests made at their Crown-street Works.)

FIG. 15.



many a really good appliance gets a bad name in this way, because people look upon it in the light of a sort of sanitary cure-all, which only requires to be administered to make everything right. This, of course, is all nonsense. The best outlet or extract ventilator in the world is utterly useless, unless it is used in conjunction with properly-placed directed and divided inlets, and the most perfectly-placed directed and divided inlets are just so much money thrown away, without an efficient outlet. Both inlets and outlets, however excellent they may be when properly used, are simply an objectionable nuisance to the occupants of the room, if they produce cold or hot draughts, as the case may be.

Here, therefore, only a few of the best known types of ventilating appliances will be mentioned, and it must be understood that the list is not in any sense given as a complete one of all, even of the best appliances in the market. Among ordinary inlet ventilators suitable for fixing in walls for natural draught, we have the Sherringham, the Tobin tube (both with numerous modifications), Ellison's conical tubes, and louvre ventilators of various types. Among the outlet ventilators opening through walls or into chimney flues, and closing against inlet draught, we have the Arnot valve, a very old appliance, but still one of the best types, and the mica flap valve, made in several forms by different makers. Among the inlet and outlet cowls, whose motive power is derived from the motion of the wind, we have the Boyle, Buchan, Banner, and many others in Britain. In Australia, several excellent cowls of these types are in use, and the sheet of illustrations (Fig. 15) shows the various inlet and outlet cowls approved by the Sydney Board of Water Supply and Sewerage, after exhaustive tests made at their Crown-street station.

Air and Air Spaces Required.—The next point to determine is as to the size of openings required, and this, of course, depends on the quantity of air needed. As has been already stated, the purity of the air

in inhabited rooms, is usually measured by the proportion of carbonic acid gas it contains, in excess of that in the purest available outside air. This is usually stated as, that two parts of this gas in 10,000 in excess of that in the outer air, is the desirable limit of impurity. Larger quantities indicate an excess of organic matter, which produces more or less close smell, as is clearly shown in De Chaumont's table, already quoted. The cubic space in a room does not ultimately affect the quantity of air necessary, in order to secure this result; but, of course, it materially affects the time in which the limit of impurity would be reached.

Thus, if we determine the limit to be allowed, of the CO_2 (carbonic acid) impurity, in order to ascertain the number of cubic feet of air per hour to be supplied, so as to maintain the air in that condition, the following formula may be used:—

$a = \frac{P}{e}$ when a = number of cubic feet of air to be supplied: P , the amount of CO_2 produced in an hour, and e , the excess of CO_2 to be permitted over that in the outer air. Assuming, then, that each adult produces 6 cubic feet per hour of CO_2 , and that the limit of excess of CO_2 is to be $\cdot002$ over that in the outer air, we have $\frac{6}{\cdot002} = a = 3000$.

That is to say, that 3000 cubic feet per hour is required to preserve those conditions, which is a little over $\cdot83$ cubic feet per second.

It should always be remembered that, while larger cubic space will delay the pollution of the air to the limit of impurity permissible, it can never replace the need for ventilation, and the time taken to reduce the air, even of a fairly large, but unventilated room, to this state, is much shorter than is generally supposed. Thus, it has been shown, that the time required for one adult to bring the air of unventilated

rooms of different sizes to the 2 parts per 10,000 of CO_2 in excess, is as follows :—

10,000 cubic feet	...	3 hours 20 minutes
5,000 "	...	1 hour 40 "
1,000 "	...	0 " 20 "
600 "	...	0 " 12 "
200 "	...	0 " 4 "
50 "	...	0 " 1 "
30 "	...	36 seconds

In considering the size of openings required, it should be remembered that in all cases, a large amount of change of air takes place through the joints of windows and doors, etc., through plastered walls and ceilings, if not painted or damp, and also through dry walls of brick or stone. This, of course, reduces the quantity of air needed through the special ventilation openings, and so enables a reduction in their size.

Cubic space, then, while not dispensing with the need for ventilation, is of benefit, because, first, it calls for a smaller change of air in rooms occupied for a limited time ; second, it increases the wall, ceiling, and usually window spaces, and so enables more change of air through these, thus relieving the special ventilation ; and, third, it renders it much easier to effect the necessary change of air without draughts perceptible to the inmates. The amount of ventilation required is sometimes stated in terms of the number of times the air in a room is changed per hour, and Messrs. B. and H. Fletcher suggest the following table for this purpose :—

ENGINEERS' RULE FOR CHANGE OF AIR.

				Times an hour.
Large halls and churches, in consequence of large cubic space	...	...	...	1
Dancing-rooms	...	...	...	4
School-rooms	...	...	...	3
Hospitals	...	...	...	5 or 6

This, however, is purely an empirical table, as obviously, the capacity and purpose of the room influences the matter. It might also be added that the floor area in proportion to the height is of importance. The air space in the upper part of a very lofty room with small floor area would be of little use to its inhabitants, and it is, in fact, generally considered that in ordinary-sized rooms, any height over twelve feet should not be counted in measuring its capacity. In many cases the cubic space, and also the floor area, is given, which, of course, fixes the height also.

The following table gives the cubic space required in Britain and Australia under various acts and authorities :

CUBIC FEET OF SPACE PER HEAD.

BRITISH			Per head.
London Board Schools ... ..	...	...	130
Board Schools (Education Department)			80
Canal boats--adults ... ..	...	...	60
" " children ... ..	...	...	40
Common lodging houses ... ..	...	...	300-400
Army Permanent Barracks ... ..	...	...	600
Prisons with separate cells ... ..	...	...	800
			Per bed.
Army hospital wards ... ..	...	...	1200
			Per seat.
Army chapel schools ... ..	...	...	200
Army infant schools ... ..	...	...	96
			Per horse.
Stables (open roofed) ... ..	...	...	1200
" (with men over) ... ..	...	...	1300
For cattle (British Local Government Board Rules) ... ..	...	...	Per animal 800
NEW SOUTH WALES—			Per head.
Factories (under N.S.W. Factories Act)			400
Lodging houses (Model By-laws under N.S.W. Health Act) ... ..	...	...	500
New South Wales Schools ... ..	...	...	100 to 150

Some of the floor spaces specified by authorities for various buildings are as follows:—

British Benevolent Asylums, 25 super. feet per head
 „ Hospitals, from 70 to 138 „ „ „ bed
 „ School Dormitories, from 50 to 60 super. feet
 per bed

N.S.W. Schools ... 8 super. feet per head

British Barracks, from 50 to 80 „ „ „ „
 according to the climate.

Coming now to the quantity of air required per head, this, as we have seen, depends on the permissible CO_2 excess impurity sanctioned. Taking the two parts per 10,000 rule, we find that each adult requires, as has been said, 3000 feet per hour, but young persons do not require so much. It has been pointed out that the amount may fairly be proportioned to the weight, so, taking that required for a man over 15 years of age at 3000 feet per hour, we have:—

At 5 years and under ... 855 cubic feet per hour

5 to 10 years ... 1414 „ „

10 to 15 „ ... 2250 „ „

Above 15 „ ... 3000 „ „

Cattle and animals breathing air, of course, also vitiate it in the same manner as human beings do, and the following table gives the air required per head per hour, taking the vitiation of air as in the preceding table:—

Horses, cubic ft. of air per head per hour ... 7920

Cows „ „ „ „ ... 7920

Pigs „ „ „ „ ... 3510

Calves „ „ „ „ ... 3120

Dogs „ „ „ „ ... 474

Cats „ „ „ „ ... 360

Rabbits „ „ „ „ ... 222

Fowls „ „ „ „ ... 22

It should be noted that the air respired at rest, and when work is being done, is very different in quantity. A man hard at work or undergoing violent exercise, such as dancing or running, will require about one-third more air than when asleep or resting.

The quantities of air above stated will form a good basis to estimate from, but it is seldom that the amounts named can be obtained, and, indeed, owing to natural change of air through crevices, it is unnecessary specially to provide for it. Capt. Galton has, however, stated that no room could be considered even reasonably ventilated as a permanent arrangement, which did not provide for a change of air of at least 1000 cubic feet per head per hour. Hood gives the following table, which certainly may be taken as a minimum health allowance:—

CUBIC FEET PER HOUR PER PERSON.

	Cubic feet per hour per person.
Ordinary Living Rooms	1200
Sleeping Apartments	900
Schools (scholars of full age)	900-1200
„ (infants)	720
„ (dormitories)	720
Meeting Rooms, Public Halls, Lec- ture Rooms	1200-1500
Ball Rooms	2100-2400
Theatres, Dancing Halls, &c.	1200 1500
Hospitals (ordinary)	1200
„ (infectious)	2100-3000

Size of Inlets and Outlets.—We now come to the question of the size of the inlets and outlets required to be provided under various authorities. Captain Galton, basing on an air supply of 1200 cubic feet per head per hour, gives the following proportions for barrack rooms. Rooms having 600 cubic feet capacity per head:—

From Roof Downwards.	1st Storey.	2nd Storey.	3rd Storey.
Outlet in inches per 600 cubic feet	1 in 50	1 in 55	1 in 60
Outlet in inches per head...	12 „	11 „	10 „
Inlet in inches per 600 cubic feet	1 in 60	1 in 60	1 in 60
Inlet in inches per head ...	12 „	12 „	12 „

In the above table, inches, of course, mean square or superficial inches, that is to say, 12 inches of opening would mean an opening 2 inches by 6 inches or 3 inches by 4 inches.

The British Education Department requires inlets equal to $2\frac{1}{2}$ square inches per child.

The New South Wales Factories Act requires that every factory or part thereof shall, when required by the inspector, be provided with inlet and outlet openings of 12 square inches; but, unless considered necessary by the inspector, this shall not apply to a factory where not more than four persons are employed, which has a fire-place and chimney, and window to open. The Model By-laws for common lodging-houses, under the New South Wales Public Health Act of 1896, stipulates that each sleeping room must have a window to the open air, capable of being opened top and bottom, and either an open fire-place or chimney, or a ventilator or ventilators aggregating 24 inches of opening for each lodger.

Hood has suggested the following table of dimensions, based on his practical experience, and taking into account the size of the room, and the number of gas jets burning, in addition to the number of occupants:—

Size of Room.	Number of Occupants.	Number of Gas Burners.	Net Size of Ventilator.
10ft. x 10ft.	2 or 3	2	9in. x 3in.
16ft. x 12ft.	3 or 4	3	9in. x 6in.
20ft. x 16ft.	4 or 5	4	9in. x 9in.

It should be noted that in all cases the openings should give the full space specified. This means, that where the openings have ornamental gratings, which may obstruct from one-fourth to three-fourths of the space, or even more, the size of the opening should be increased accordingly. It is unnecessary in this

work to enter into the more elaborate schemes of ventilation for large buildings, requiring mechanical means, in most cases, for efficient working, as these are not likely to be met with in the general work of a sanitary inspector. The only exception, probably, would be in the case of factories, or noxious trades, and these would usually call for the intervention of a skilled engineer.

Illuminating and Heating Burners.—In regard to the vitiation of air by illuminating and heating gas-burners, the information given in text-books is usually vague in the extreme. The vitiation is commonly based on the number of cubic feet of gas burned, and that is assumed at 3 cubic feet for an ordinary gas burner. This is altogether misleading; an ordinary gas burner may consume anything, from 3 feet to 8 or even 10 feet per hour; and, further, there is a vast difference between the gas burned to give equal light in different gas burners, or even in the same burner when properly and improperly used. It is unnecessary to enter into the reasons which influence this matter, beyond stating that where inferior burners are used, or even good burners turned too high, the gas is imperfectly burned. This results not only in much larger quantities of gas being used than is necessary for the illumination, but also in the escape into the room of large quantities of unburned gas, and, what is even more dangerous, of a considerable amount of imperfectly burned gas, in the form of the dangerous blood poison carbonic oxide (CO). This is the white damp of the coal miners, which caused so serious a loss of life recently at the Stockton and Dudley pits in the Newcastle district.

The latter gas is also formed in large quantities where a heating gas-flame is allowed to come in contact with cold surfaces, as is sometimes the case in gas-warmed water-heaters. This has, before now, in the case of such heaters fitted over baths in confined unventilated bathrooms, brought death to unthinking users. The same thing may occur in factories when such heaters

are used, for instance, in heating tailors' irons, and for this reason it is very justly stipulated in the N.S.W. Factories Act that, heating appliances either for warming or trade purposes, must have a sufficiently large flue to carry away all products of combustion, but not less, in any case, than 4 inches diameter or equivalent area. This is a very necessary provision, which might reasonably be insisted on in all gas-heaters, but particularly in that class known as "gas water-heaters" when fitted in small rooms.

The following table will give some idea of the light which can be obtained from different gas lighting burners, and so incidentally the amount of gas which must be burned to give equal light.

GAS REQUIRED TO PRODUCE A LIGHT EQUAL TO 288 CANDLES FOR ONE HOUR, BEING THE EQUIVALENT OF THE INCANDESCENT ELECTRIC LIGHT PER BOARD OF TRADE.

Kind of Burner, &c.	Duty in Candles per cubic foot of Gas Burned.	Total Gas Required per Hour.
Common open flame—		
Worst	0.5	576 cubic feet
Best	3.0	96 " "
Argand good type	3.5	83 " "
Regenerative gas lamp—		
From	6.0	48 " "
To	7.0	41 " "
Welsbach Incandescent Light—		
From	12.0	24 " "
To	17.0	17 " "

From this it will be seen that in the worst form of open-flame gas-burner, such as is too often found in workshops, 576 cubic feet of gas has to be burned to produce the same light which can be obtained from the incandescence gas-burner, with a consumption of only 17 cubic feet. The proportional vitiation of the air is obvious. It is probably not far from the truth

if we assume that the average light obtained from the ordinary form of open flame burner in common use, does not exceed 2 candles per foot of gas burned. This means that 144 feet of gas has to be burned in order to produce the same light obtainable from the incandescent gas-burner with 17 feet.

Measurement of Air Currents.—In tracing the source of cold draughts in a room, the course of the air currents may be easily traced by means of a piece of ordinary brown paper rolled up, lit, and blown out so as to smoke. In this way the inspector may often locate the source of a draught which has led the occupants to close up ventilation openings which possibly have nothing to do with the draught felt.

The velocity of air currents is measured by an instrument called an "anemometer." This is simply a little windmill wheel 2 to 3 inches in diameter, which actuates clockwork, and registers on a series of dials the lineal dimension of the current of air passing during the period of observation; this, measured by the area of the opening in which the instrument is held, gives the quantity of air passing. Thus, supposing the opening measures 2 ft by 5 ft., and the instrument shows a linear velocity of 200 feet in one minute's observation, the quantity of air passing through is $2 \times 5 \times 200$, or 2000 cubic feet per minute. A simple method of approximately measuring the velocity of currents too slow to be measured by the anemometer, is by observing the deflection of the flame of an ordinary candle. A current velocity of .4 feet per second will deflect or incline an ordinary candle flame to an angle of 65deg. with the horizontal line, .5 feet will deflect to 60deg., .75 feet to 50deg., 1 foot to 46deg., and 1.6 feet per second to 30deg.

The tests for various impurities in the air have already been given; but a simple and safe indication of the presence of carbonic oxide is afforded by the fact that a mouse shows symptoms of poisoning by this gas in one twentieth of the time that a man is affected.

Smoke Nuisance Prevention :—Smoke nuisance prevention is becoming an increasingly important part of a Sanitary Inspector's work, and the Smoke Nuisance Prevention Act enables action to be taken in this matter. In order to understand the possibilities in the direction of smoke prevention it is needful to have a knowledge of the laws governing the combustion of fuel. This is the more necessary because the Act specifies that smoke is to be prevented so far as possible, so that it is necessary for the Inspector to know what is possible.

Combustion is really a chemical action which requires for its operation the presence of certain elementary bodies in proper proportion to enable them to combine, and also calls for a sufficiently high temperature to enable that combination to be accomplished. All the combustibles commonly in use, such as coal, wood, coke and charcoal, consist almost wholly of combinations of two elements, viz., carbon and hydrogen, or of carbon alone, and the same remark applies to ordinary coal gas, and to kerosene oil, and coal tar, all of which are sometimes used as fuel for heating purposes. Coal, wood and coke also contain a certain proportion of ash, or incombustible matter, which, if in excess, adds to the difficulty of the smokeless combustion of the fuel. Coal and coke, and also coal gas, likewise contain a small percentage of sulphur, which burns to sulphurous acid, working destruction on organic substances and colours, when gas is burned in unventilated rooms. The sulphur in coal also sometimes appears in coal gas, as sulphuretted hydrogen, which not only constitutes a nuisance from its offensive smell but is also poisonous, and so dangerous to health. Under the more recent Acts relating to gas works in N.S.W., the gas must be purified entirely from sulphuretted hydrogen, but under the older Acts this is not stipulated for. Imperfectly purified gas thus often contains sulphuretted hydrogen, which is also the characteristic gas from decaying sewage matter ; and

cases have been known here, when what was thought to be an indication of defective sewers, or house fittings, has been traced to the escape of such unpurified gas from a gas pipe. Visible smoke does not arise from coke or charcoal, although the invisible, but highly-dangerous gas carbonic oxide, often does. This, however, is not dealt with under the Smoke Nuisance Prevention Act, although it certainly should be. Visible smoke arises practically from the imperfect combustion of what are known as the volatile constituents of the fuel, which come under the head of what are called hydro-carbon gases of various kinds, and from tarry matter in the form of vapour. It is these volatile matters which cause the well-known yellow flame produced during the combustion of coal or wood, and it is from the non-ignition, extinction, or partial combustion of those gases and vapours that smoke arises. The ordinary or flaming coal contains a considerable proportion of these volatile matters, and what is known as non-flaming or smokeless coal, more nearly resembles coke or charcoal in that they contain little or no volatile matters, and so produce little or no yellow flame, but only the pale blue flame arising from the combustion of carbonic oxide gas, and which may be often noticed on the surface of a mass of burning coke.

Newbigging gives the following as the composition of an average coal, so far as the combustible matter is concerned:—Volatile—Gas 18 per cent., or about 403 lbs. representing about 10,000 cubic feet of inflammable gas; tar, 5 per cent. or about 112 lbs. Non-volatile—Coke, 68 per cent. or about 1523 lbs. The non-volatile coke part can, however, also be converted into gas, either in the form of what is called “producer gas,” the combustible portion of which is chiefly in the form of carbonic oxide, or as what is known as water gas, which in addition to the carbonic oxide, contains a considerable proportion of free hydrogen, derived during the process of manufacture, from the decomposition of the water in the form of

steam, which is brought into contact with the red hot coke, and so gives the name water gas to the resultant product. By what is called the Dellwick process, about 77,000 cubic feet of water gas can be made from a ton of coke, so that from the 1500 odd lbs. of coke driven from the ton of coal, about 52,000 cubic feet of this gas can be obtained

When fresh coal is fed into a furnace on the top of the red or coked fuel on the firebars, the heat of the red fuel immediately begins rapidly to heat up the green or fresh fuel. This has the effect of starting what is in fact the dry distillation of the coal thrown on. Dry distillation means the rapid driving off of all the volatile constituents in the coal. Of these the tar vapours appear as dense greenish smoke, and the rest partly as bluish or grey smoke, but mostly as invisible gases. If air is not supplied to these volatile matters at this stage, or if the temperature is too low for ignition, the whole of these volatile matters pass up the chimney, unburned, and give rise to dense, greenish-black smoke. Mere heat without air is equally inefficient to produce combustion, unless the chimney is so short that the gases can arrive at the top sufficiently heated to enable them to inflame when they reach the open air. If this happens, the smoke and gases inflame, and disappear as visible smoke, but a large proportion of the fuel is, of course, uselessly burned, where it can do no good in heating the boiler or furnace. If the heat is sufficient for ignition, but the air supply insufficient to effect complete combination, the gases inflame in a long, smoky, reddish-yellow flame, which tails out for a great distance along the furnace flue. If such a flame enters the tubes of a tubular boiler, its heat is so quickly abstracted by the sides of the water-surrounded tubes, that it is rapidly reduced below the combining temperature, and the flame is thus extinguished before it has completed its combustion, resulting in the production of dense rolling masses of

black smoke, similar to what is often seen leaving the funnels of steamers, particularly of the smaller class.

If the heat is sufficient for ignition, and the air supply ample in quantity, and so distributed as to mix throughout the volatile gases and vapours, as fast as they are produced, we have then perfect conditions of combustion. The flame is greatly shortened, and when the mixture of air is perfectly done, the flame assumes the bluish appearance of gas burning in an atmospheric burner. Under those circumstances the flame *completes* its combustion before it reaches the tubes in a tubular boiler. Even if it does enter the tubes, and is extinguished there, or by contact with other comparatively cool surfaces, no smoke is produced, although the dangerous but invisible gas, carbonic oxide, usually is, under such circumstances.

Care must be taken that the air admitted to consume the gaseous, or flaming part of the fuel, is not admitted in too large amount, or in a solid current at one point of the furnace. In the former case the combined mass of combustible gas and air is in part, or even wholly, cooled down below its combustion point, and smoke and waste of fuel results. Further, the mass of cold air admitted above the fire bars, as it usually must be for reasons to be explained, may not only extinguish the flame from the volatile matter, but checks the chimney draught, so decreasing the passage of the necessary air through the fire bars. This has the effect of slowing the rate, and consequently the intensity of combustion of the red coked fuel there, besides seriously lowering the temperature of the whole of the combustion gases coming in contact with the heating surfaces of the boiler, or of the surfaces of the material to be heated in the furnace. If the air is admitted in a mass at a point, instead of being distributed over the entire area of the distilling fuel, clearly the intimate mingling of the air with the gases, which is neces-

sary for combustion, cannot take place. The result is, that the air and gases pass in separate masses into the chimney, and very often before thorough mingling can be effected there, the masses have cooled below the combustion temperature, so that here again smoke and waste of fuel may occur.

Ordinary coal gas is simply the volatile or flame-producing part of coal purified, practically, the only combustible volatile part withdrawn from it, during its manufacture, being the coal tar vapour which is condensed to coal tar liquid in the gas-works. The behaviour of ordinary coal gas in burning, therefore furnishes to us valuable information for application to the burning of the volatile part of coal or wood fuel in a furnace. If we take one of the ordinary heating burners or gas rings, we shall find that the gas is burned on what is called the Bunsen, or atmospheric, principle. That is to say, a considerable proportion of the air is caused to mix with the gas in the body of the burner, before the issuing mixture is ignited at the point of combustion. Here, then, we have exactly the same conditions pointed out as desirable in the furnace. It will be noticed that in Bunsen burners there is always an opening for the admission of air, as well as a small gas nozzle for the admission of the gas. When the air and gas openings are properly proportioned, the burning flame is short and of a blue colour, there is no smoke visible, and a white tile or plate placed in the flame for a moment is not discoloured by smoke. This tile or plate is, of course, cold as compared with the flame, and so extinguishes it when brought in contact with it, just as the tubes would do in the boiler. This illustrates the conditions in a furnace when proper mixture of air and sufficient temperature exists. If, now, we close up the opening, for the admission of air to mix with the gas, so that the gas reaches the combustion point unmixed with air, a great change in the appearance of the flame takes place. It instantly lengthens to from double to even thrice or four times its former length, accord-

ing to the sectional area or solidity of the jet ; it turns dull reddish-yellow in colour and smokes. Here, then, we find the conditions when a sufficient quantity of air is admitted, but in mass, at a point, so that efficient mingling is impossible. If the cold tile or plate is now placed in this reddish-yellow flame, it will be found to be instantly coated with a thick layer of deposited soot, which is, in fact, the *black* smoke formed from the flame, and arrested by contact with the cold surface. Here, then, we have the conditions, found when an already smoky flame is extinguished before completing its combustion by comparatively cold surfaces, such as the tube in our boiler. The actual conditions of smoke production may be more clearly illustrated by using a square of wire gauze, instead of a cold tile or plate. The wire gauze will extinguish the flame by cooling it, just as the cool surface of the plate does. It does not, however, arrest the resulting smoke, but permits it to pass through its interstices, and the dense black smoke so arising may, in this way, be made clearly visible on a small scale, and it will be noticed that the smoke from the yellow-red flame is greatly increased in volume when the flame is partly extinguished by this means. If, now, the smoky yellow flame be exposed to a current of air, a considerable increase in the density of the smoke will be observable. This is due to the cooling of the flame, resulting in its partial extinction by the cooling action of an excess of air improperly applied, and if the air current is gradually increased in speed, the flame will ultimately be entirely extinguished by this cooling action, which is, in fact, simply the every-day operation of blowing out the light. In this connection it is important to have some idea of the temperatures at which the chief combustible gases, found in ordinary fuel, combine with the oxygen of the air, that is to say, ignite. These gases are hydrogen; hydrocarbons (heavy and light); and carbonic oxide, from the decomposition in process of combus-

tion of the non-volatile or solid coke part of the fuel. Of these, hydrogen and the heavy hydrocarbons ignite at about 1022 deg. F. Carbonic oxide (the white damp of coal mines), 1202 deg. F. Light Hydrocarbon (or marsh gas, the fire damp of coal mines), 1436 deg. F.

If cooled below these temperatures the flame of those gases is extinguished, and if not heated up to them, they cannot ignite. At much higher temperatures another action comes into play, which has the effect of rending the elements of the gases asunder, and of permitting in some cases fresh compounds to be formed. This is what takes place in dry distillation of coal, when the volatile portion is rent asunder from, and driven out from the carbon, or solid coke residue. Thus hydrogen, carbon and oxygen cannot remain in combination at a temperature of 4530 deg. F, and carbonic acid (CO_2) the product of the perfect combustion of the carbon part of fuel, is dissociated into its elements carbon and oxygen, at 1832 deg. F. The latter action especially is very important in smoke prevention, and it materially influences the possible passage of air, through a bed of coked fuel on the firebars of a furnace, when such is relied on to supply the gases above the fuel with air. Also the entire conversion of the fuel, including both the volatile and non-volatile parts, into gas, which takes place in gas producers, in making producer gas, and also water gas, is dependent entirely on dissociation.

As giving some idea of what the temperatures mentioned above indicate, it will be useful to remember that a red heat which is just visible in the dark, means a temperature of 977 deg. F. Dull red heat, 1290 deg. Cherry, 1470 deg. Clear red, 1830 deg. Deep orange, 2010 deg. Clear orange, 2130 deg. White, 2370 deg. Bright white, 2550 deg. Dazzling white, 2730 deg.

In regard to the proportions of air which will extinguish the flame of the ordinary combustion gases,

the following furnishes the limits of air to the gas, at which combustion can take place. The most intense combination occurs when the mixture is the mean of the two extremes, but with a *smaller* or *greater* admixture of air, ignition cannot take place, or in other words, flame will be extinguished.

IGNITING MIXTURES.

- 1 measure of coal gas will ignite with from 2·8 to 16·0 measures of air ; mean, 9·4.
- 1 measure of hydrogen will ignite with from 1·4 to 20·0 measures of air ; mean, 10·7.
- 1 measure of marsh gas will ignite with from 7·7 to 20·0 measures of air ; mean, 13·8.
- 1 measure of carbonic oxide will ignite with from 1·3 to 7·7 measures of air ; mean, 4·4.
- 1 measure of acetylene will ignite with from 1·2 to 33·0 measures of air ; mean, 17·1.

Combustion in Furnaces.—These figures are of much interest, as illustrating a point of great difficulty in the smokeless combustion of coal or wood. It will be noticed that comparing the mean mixture of air and gas for coal gas (the flaming part of coal), and carbonic oxide (the combustible gas from coke), they are as 9·4 to 4·4, that is to say, the best mixture for proper combustion in coal gas is 9·4 cubic feet of air per cubic foot of gas, while for carbonic oxide it is only as 4·4 cubic feet of air to one of gas. Now, coal gas forms nearly the whole of the volatile matters which are rapidly driven off from the coal when thrown on the top of a hot red fire, and when these gases are thus driven off, only coke remains, which gives off the gas carbonic oxide in its combustion, but much more slowly than the coal gas is given off. Now, as bulk for bulk, the coal gas requires more than double as much air for its combustion than does the coke gas, and, as the latter passes off much more slowly, clearly the quantity of air to be admitted above the fire must vary greatly, according to the state of the fire, being greatest when the fuel is

freshly thrown on, and least when the flaming has disappeared, all but the blue flame of the carbonic oxide from the coke.

This involves an attention in firing it seldom receives, even if the need for it is understood, which too often is not the case. If the draught doors are regulated to supply enough air for the volatile part, then there is too much for the fire when burnt up, and the steam in the boiler or heat in the furnace goes down. If the draught is regulated so as to suit the burnt-up fire the heat is better maintained, but smoke is inevitable with each firing. In practice the smoke is often preferred to the trouble of regulating the draught.

Draught.—The idea held by many firemen, as a sort of fetish, that sufficient air can be got *up through* the fire bars, and that any air admitted over the fires cools the furnace, is entirely erroneous. The oxygen in the air is all that is of any use in combustion, and if the air has to pass up through any reasonable thickness of red or coked fuel, the whole of the oxygen it contains is combined with the coke, and passes upwards either as carbonic acid, or carbonic oxide, according as the fire is thinnish, or very thick over the bars. Carbonic acid cannot give up any oxygen to effect combustion of the inflammable gases *over* the fuel, there is nothing but the nitrogen left of the air which has passed through the red fuel. Carbonic oxide not only cannot supply oxygen, but actually requires *more* oxygen to complete the combustion of the carbon it contains, otherwise so much fuel will be wasted. Clearly, therefore, there should be a separate air supply above the fire in order to furnish the oxygen required for the combustion of the coal gas and tar vapours (hydrocarbon), and of the coke gas (carbonic oxide); and just as clearly in all cases where hand firing at fixed intervals is practised, that air supply must be greater immediately after firing than during the period of the combustion of the coked coal.

Continuous Firing.—If the coal can be continuously and regularly fed to the furnace, then the formation of the volatile or coal gases, tar vapour, coke gases, and direct combustion of the coke, go on together, and without variation in the rate of production of any one of them, and this enables the conditions as to draught, and distribution of air, to be adjusted so as to secure the best results; and left to work regularly, a state of things which as has been pointed out is impossible with hand firing.

Mechanical Stokers.—Machines of this class are obtainable, and are called mechanical stokers. These are usually of one of two main types, the *coking* and the *sprinkling* machines. In the former, the coal is continuously fed into the furnace at the front end, and worked by slowly moving firebars right to the back of the furnace, by which time it is reduced to ash, and drops into the ash pit below. In the other class, the sprinkler, a moving arm continuously throws, or sprinkles, a small quantity of coal over the entire surface of the burning fuel in the furnace, thus securing the same result.

With these machines, perfect results as regards smoke prevention can be attained.

General Smoke Preventing Machines.—The other types of smoke consumers, as they are often erroneously called (the proper term being smoke preventers), are legion in number, most of them dealing with methods of supplying and distributing air to the furnace. Many of them are utterly useless, being designed without any real knowledge of the requirements. Others are good, if attended to, and regulated according to the state of the fire (but this is often neglected), and others are so far self adjusting, in that they admit a maximum supply of air, on opening and closing the furnace door, which is gradually reduced to the normal, in a time which can be to some extent adjusted.

Hand Firing.—Hand firing, however, is practised in by far the largest number of furnaces, and there

can be no hesitation in saying that, in the case of any ordinary furnace, such as a steam boiler furnace, there is no excuse whatever for the production of black smoke. In nine cases out of ten it arises from either careless or ignorant firing, insufficient boiler power necessitating forced firing, or insufficient chimney power, or cracked flues, &c., which renders the draught needed, properly to burn the fuel required for the furnace, impossible. In the tenth case the cause will probably be found to be inferior and dirty fuel, combined with a fireman who does not know enough to enable him to burn it properly, or it may be a skilled fireman, who is condemned to the well-nigh impossible task of making inferior rubbish do the work of good fuel. The skilled Inspector will be able to place the blame on the right shoulders in such matters.

Deoxidizing Furnace.—In concluding this subject it should be pointed out that, in some furnaces for certain purposes, the prevention of smoke is almost impossible. For instance, in brick-burning, in open clamp kilns, the prevention of smoke, and offensive vapours, is practically impossible; but in what are called the Hoffman continuous kilns, neither smoke nor nuisance from vapours need exist. Again, in certain metallurgical processes, what is called a deoxidizing flame is needed. This means that the supply of oxygen from the air must be intentionally restricted, so that the flame will, so to speak, be greedy for oxygen. This condition is, for obvious reasons, very apt to result in the production of smoke, which might fairly, in some cases at least, be classed as non-preventible.

Summary of Requirements.—In concluding this important subject, the following summary of requirements in smoke prevention may profitably be given:—

Construction of Furnace.—1. There must be arrangements for admitting the air over, as well as under, the burning fuel. 2. The air over the fire should be admitted so as to mix thoroughly with the

combustible gases arising from the fuel. 3. There should be means for specially regulating this portion of the air supply, and it should, if possible, be heated before mingling with the gases over the fuel. 4. The air supply above the fire must not be less than the quantity required for the fuel, nor must it be in any great excess, as in either case smoke would result.

Hand-firing.—In hand-firing, the great point is to imitate the action of a mechanical stoker, as closely as possible. That involves: 1. To fire often, and either to spread the coal evenly, but thinly, over the entire surface of the furnace, as in the sprinkling machines, or to place it in considerable thickness just inside the furnace door, and work it gradually backwards over the furnace during successive firings, as in the coking machine. 2. To attend to the air supply *over* the fire, regulating it according to the state of the fire, and see that the bars are kept clean. In some cases, the furnaces are fired alternately along each side of the furnace space, and, sometimes, a low division wall is used to separate the two sides of the furnace. This is, of course, done so that the heat from the bright fire will assist the heating up and distillation of the green coal on the freshly fired side. From what has been said, it will be obvious that this arrangement, although an excellent one, cannot do away with the need for over fire air supply, although it may, to some extent, reduce the necessity for adjusting it between firings.

Finally, it may be mentioned, that allowing double the theoretical quantity needed, which is often done in order to ensure a full supply of oxygen to the fuel,

Average coal requires 294 cubic feet of air per lb.

Average coke requires 269 cubic feet of air per lb.

Average wood requires 161 cubic feet of air per lb.

Average charcoal requires 294 cubic feet of air per lb.

Coal is sometimes entirely converted into gas before being burned in a furnace. This has the advantage of rendering the regulation of the air

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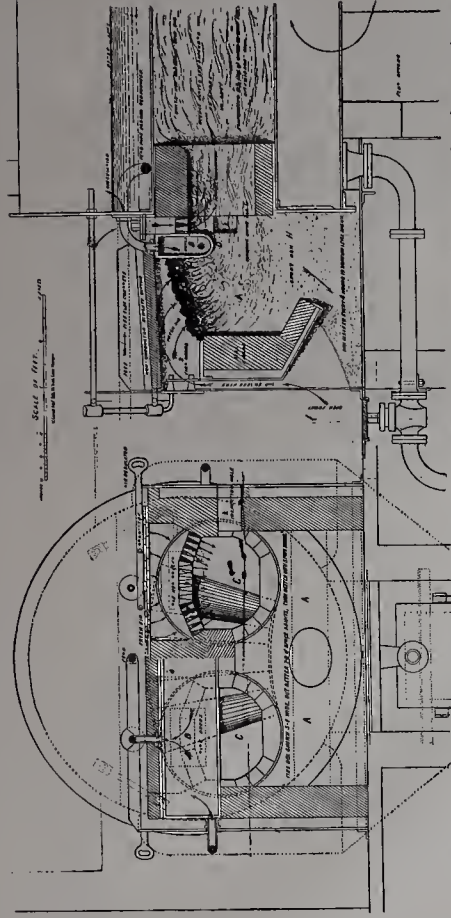
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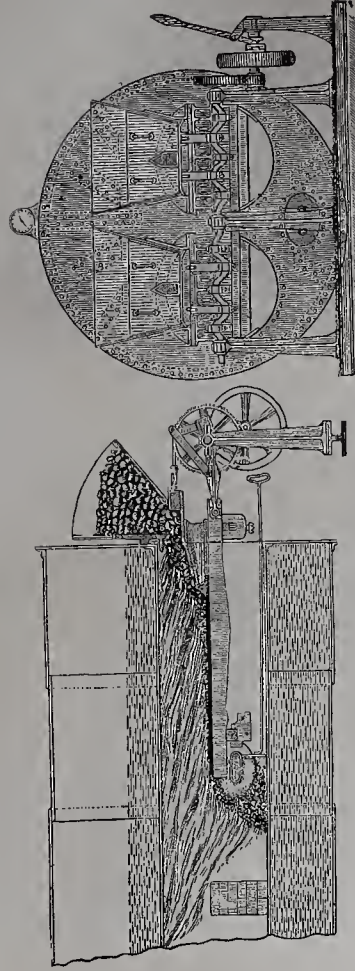


SMOKE PREVENTION—A BOILER FIRED BY PRODUCER GAS. FIG. 16.



DESCRIPTION.—A, gas producer; B, feed water-heater; C, brick-lined combustion chamber; I, inspection hole; H, ashes. In this producer the draught passes downwards through the green fuel and through the incandescent fuel against the feed water-heater which forms the bridge, the producer gas meeting the heated air supply, passing downwards through the red-hot perforated bricks at the top of the combustion chamber, and so producing a smokeless flame, which passes on into the boiler flue.

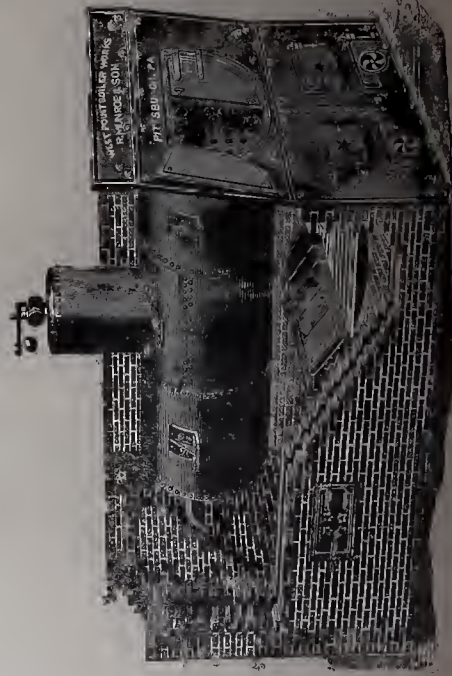
FIG. 17.



SMOKE PREVENTION.—SINGLAIR'S MECHANICAL STOKER.
(COKING TYPE.)

SMOKE PREVENTING FURNACE.

FIG. 18.



Tubular Boiler, showing air admitted to upper side of fire bars through gratings forming the furnace bridge.

supply to the fuel exceedingly easy, and also enables an adjustment of the amount of fuel burned to the requirements, which is not possible in the ordinary method of using coal in the furnace.

The illustration Fig. 16 shows this method of firing. The chamber in front of the boiler is filled up with coal or coke, and the air allowed to pass up slowly through it. This effects the combustion of the lowest layer of the fuel, and the heat so obtained heats the overlying fuel to a high temperature, so decomposing the CO_2 from the lower layer into CO , and using up the heated coke in doing so, then passing up through the green fuel towards the top, it distils off the volatile gases, and coal and coke gases pass on into the boiler flue, which has no fire bars. Here the gases meet the air supply entering through the tubes in front of the flue, and combustion takes place. The flue is lined with fire bricks for some distance so as to enable the gas flame to complete its combustion before coming in contact with the cooler iron surfaces beyond. The apparatus for converting the coal into gas is called a gas producer, and there are several types of these, varying in details, such as the Siemen's, the Wilson, and the Dowson producers.

Fig. 17 shows a section of a mechanical stoker of the coking type, and Fig. 18 shows a method of admitting and distributing air at the furnace bridge, the boiler shown in this case being of the tubular type so often referred to above.

CHAPTER IX.

BUILDINGS.

While it is unnecessary for the Sanitary Inspector to be a tradesman, it is of much advantage to him to be familiar with the construction of buildings. In fact, a knowledge of the operations common in building, and of the methods in which buildings are constructed, is a necessity if the inspector is to judge of work and conditions, much and many of which are concealed from view, so that a knowledge of their possible existence is obvious only to one who has some idea of what is likely to be "under the surface."

Of course, with the aesthetic side of the structure, the Sanitary Inspector has nothing to do, except in so far as decency is concerned. It is with what has been termed the sanitary construction of the building that he is chiefly interested. Excluding drainage, plumbing fittings, and ventilation arrangements, which are dealt with under special chapters, sanitary construction resolves itself into the prevention of the excess of damp and of ground air, and the arrangement of parts, so that walls, floors, and ceilings can be thoroughly and effectually cleaned, and kept clean, and to this end light, and plenty of it, is an important factor.

Damp.—Damp in a house may arise from several directions. Many soils, even if drained, and so not absolutely wet, are yet more or less damp. The condition may be illustrated by the fact that if we place an impervious body like a sheet of iron on the surface of even an apparently dry soil, after a time the under-surface of the iron next the soil will be found to be quite damp and moist. This shows how damp arises even in unexpected cases. The foundations of

a wall resting on such a soil absorb moisture from it ; and, as the materials used for walls are usually more or less porous, this damp rises up by what is called capillary attraction. The height to which moisture will rise in a wall depends on the nature and porosity of the materials and the dampness of the soil. It is sufficient to say that it has been known to rise up seven or eight feet above the point of contact with the damp soil. This damp, showing as it does on the inner surface of the plastered wall, is evaporated off into the house, causing cold and unhealthy conditions and destroying wall coverings, etc.

Damp Courses. — In order to prevent this, continuous layers of some material, impervious to moisture, are inserted in the walls above the level of the earth surface, and below the level of the floors. These are called damp courses, and should be placed in every wall resting on the soil, or, at the least, in every outer wall. The materials used for this purpose are various. In the cheaper class of houses two layers of slate bedded in Portland cement, and having the joints of the lower course covered by the solid of the course above, are often used. This forms an efficient damp-course, but, being unyielding, and not very strong, it is apt to be fractured by settlement of the building, or even broken in the operation of building the wall above it, when it of course becomes more or less useless for preventing the rise of damp.

Other materials used for this purpose are sheet lead (which is a good and durable material), coal tar bitumen asphalt, which is too brittle to be reliable. Natural asphalt mastic, which is a good material, too tough to be readily fractured, and sometimes tarred felt, which is, however, neither durable nor very reliable. The material, called Ruberoid, has also been recommended. This being chiefly made up of natural bitumen, as a waterproofing material, should be durable and reliable, but its thinness and want of body to resist the rough work of building, must

render it inferior to the thicker coating of well laid natural asphalt mastic. Perhaps, the best available material is the salt-glazed stoneware slabs, which are specially made for the purpose. These slabs, which are constructed of a perfectly impervious material, stronger than ordinary brick, are made the full thickness of the wall, and formed with grooved joints along each side. When laid side by side on the wall and bedded and properly jointed in good Portland cement, they form an ideal damp course, strong, durable, perfectly impervious to damp, and not liable to fracture. Indeed, so strong are they, that they actually form a bonding course to the stone or brickwork, thus considerably adding to its stability. They have also another advantage, in that being perforated throughout their length, they thus also form a continuous ventilating course, to the space under the floors, and extending right round the building. The importance of this provision will be referred to presently. The proper position for damp courses in walls is, for ground damp prevention, at a level just above the surface of the ground, and under the level of the wall plate, or sleeper, as it is called, on which the joists or timbers, which support the floor, rest. When placed in this position, the damp is not only kept well below the level of the floor, but is also prevented from reaching the lowest timbers in the wall, which it might cause to decay.

When the ground level outside the wall is above the level of the floor inside, which is sometimes the case on a sloping site, or with a partially sunk basement, a different damp-preventing provision is necessary. The best way is to build a strong wall a little distance from the wall of the house outside, so as to support the earth some distance back from the house wall, thus forming a dry area, or air space. This air space should be continued downwards to such a depth that the bottom is sufficiently far below the level of the floor to enable a damp course to be inserted in the manner above described. In such a

case the bottom of the area is virtually the surface of the ground. Of course the bottom of this area must be paved and kept properly drained, to prevent water accumulating in it. Sometimes this area is left open, and sometimes it is closed on the top. In the latter case special provision should be made to prevent the damp being conducted from the earth by means of this covering, to the house wall. Such an open area, or air space, is undoubtedly the best way to preserve a wall dry, under the ground line, but it is rather expensive. A cheaper way, which is perfectly effective when properly done, is to place a damp course of mineral bitumen, in the position in the house wall relative to the floor, already described, and to continue it as a coating upwards on the outside of the wall to a point well above the ground level. The earth outside may rest against such a vertical protection, but the damp cannot penetrate, and the wall is so kept dry.

Portland cement rendering, is practically useless for this purpose, as, although it is sufficiently impervious to prevent any appreciable leakage, say, from a reservoir, yet it cannot prevent sufficient moisture passing to render a wall so damp as to be unhealthy. In dealing with existing houses, whose walls are damp for lack of provision of this kind, it is absolutely useless to attempt to prevent damp by coatings applied *inside* the walls. Water has so much power of penetration that it will in many cases peel off any thin coating applied on the inside. Besides, the damp, if prevented from evaporating off the inside surface of a wall by any waterproof coating, will rise still higher in the wall, unless means to avoid it are adopted, and this can only be done by a damp course passing through the wall. In existing buildings, where no damp course has been originally provided, it can be inserted, without danger to stability, by cutting through the wall in short lengths, inserting the damp course, making up the wall in strong Portland cement, and wedging it well above the damp course, then

cutting out an adjoining short section, and so on around the building. For this class of work, the stoneware slab damp course is especially suitable. Of course, the operation is infinitely more costly than if it had been done when the house was building, but such a provision is often necessary to render a house healthy, and its insertion in this way presents no difficulty to a skilled builder. In cases where the ground is above the floor level, an area should, of course, be formed as already described, in addition to the damp course; and in such a case the alternative method of putting in a bitumen damp course is not suitable, because of the difficulty of making up a wall securely after its insertion. Such a damp course would be difficult to insert with any assurance of its continuity under the conditions necessary in work so done.

In addition to a damp course for preventing the rise of damp in walls from the ground, damp courses are often inserted at the top of walls having parapets, that is, whose tops are not protected by the roof, in order to prevent rain soaking down into them. Damp courses such as described are not, however, so necessary in these cases, and a fairly close-grained stone coping well weathered, that is to say, sloped so as to throw off the water, or a rendering of well-trowelled Portland cement, protecting the exposed top of the brickwork, is usually effective. Of course, in ordinary eave roofs, as they are called, that is, roofs covering and so protecting the tops of the walls, no such precaution is necessary.

In all cases where houses are built in loamy or clayey soil, in fact in every case except that of sites composed of perfectly water free gravels, coarse sand or rock, sub-soil drains, or weeping drains, should be provided round the foundations of all the outer walls, and more particularly on the sides where the strata slopes towards the house, especially if the floor level there is below the ground surface. These drains, which should be laid close to the footing, or

spread out, of the walls when they rest on the ground, are composed of plain red clay, unglazed pipes, without sockets, or sometimes of ordinary salt-glazed stoneware pipes, perforated with holes all round to allow the ground water to drain into them. These drains are merely intended to provide permanent channels, into which the ground water can drain freely, and through which it can find its way readily to a suitable outfall. To fulfil this object the following points must be attended to: The ground to receive them must be carefully levelled close to the footings, and the bottom of the drain should be kept about an inch lower than the ground on which the footings rest. The joints of the pipes should not be closed water tight, as in ordinary drains, but should be protected by loosely-placed stones, which, while preventing the access of the soil, will yet allow the ground water to percolate to the interior of the pipe. The space over these drains, between the earth and the house wall, should be filled up with stones broken small, or coarse gravel, free from sand, or earthy matter, so as to allow any water leaking into this space from the soil to find its way easily down to the drain. This broken stone filling should be carried up to within 6 to 12 inches of the surface, but should be protected from the inflow of mere surface water, for which such drains are *not* intended. The outfall of such drains should always, when possible, be to some natural storm water channel. If it is absolutely necessary that it should discharge into a drain, special precautions must be taken to prevent the drain air being conducted by this means around, and possibly into, the house. The best method of doing this, will be described in the next chapter.

Subsoil Drains. — Where the soil is naturally damp, drains of a type similar to those just described should be laid in parallel lines all over it. The depth and spacing of the lines of those drains should be such, that the underground water level will have a slope of

1 in 12 towards them. That is to say, if the drains are, say, 24 feet apart, they must be 2 feet deep in order to drain the soil to a depth of, say, a minimum of 10 inches below the surface; 30 feet apart would require 2 feet 6 inches depth, 36 feet, 3 feet deep, and so on. Of course if it were desired to drain the soil to a greater depth than 10 inches below the surface, the depth of the drains, in relation to their distance apart, would require to be correspondingly increased.

The walls of houses, particularly when exposed to drifting rains, are often apt to be damp from this cause. This arises from the soakage of the rain water through the bricks or stone of which the walls are built.

Mr. Jas. Nangle, in his book on Australian Building Practice, has pointed out that the ordinary bricks used about Sydney absorb from $3\frac{1}{2}$ to as much as 11·7 per cent of their weight of water. Such bricks, as the latter absorption indicates, would allow rain beating on them to pass through fairly freely, and produce very damp walls on the inside. Some protection is therefore necessary. In Scotland the outer walls, which are usually of 2ft. thick stone work, are always protected by having the plastering done on laths, fixed an inch or so from the inner surface of the wall, thus leaving an air space between the inner side of the wall and the plaster finishing. In Australia the almost universal practice is to plaster on the inner side of the wall itself.

Hollow Walls.—The safeguard of the Scottish air space is thus lost in Australia. Recently, however, it has become more the practice here to introduce such an air space within the thickness of the brick wall, brick being by far more largely used than stone. This is called the hollow wall method of building. In this the outer skin or surface of the wall is formed of half brick thickness, that is $4\frac{1}{2}$ inches thick, and forms merely a break-wind, or screen, to the inner portion of the wall, which supports the roofs, floors, &c. This inner wall is separated from the outer

screen wall by a continuous air space $\frac{1}{4}$ -brick wide or $2\frac{1}{4}$ inches across. Drifting rains can penetrate only to the inside of this outer skin, down which the moisture runs, so that the inner wall is preserved dry. The outer wall being too thin to be stable if unsupported, is steadied by ties built into it, and into the inner wall, and crossing the air space at short intervals.

These ties require to be specially made, so as to prevent the moisture from the outer wall passing by their aid across the space to the inner wall, which would, of course, destroy the efficiency of the intercepting air space. This is usually effected by crooking the ties either up or down, so as to cause any water passing from the outer skin to drop from them down to the bottom of the open space. Where the space between these walls has to be closed in, as at the sides and tops of windows and doors, special precautions against the passage across of water must also be taken. To this end, small metal gutters are provided, built into the outer wall over such openings, and long enough to project 6 inches or so beyond each side. These have the effect of collecting any water running down the inside of the screen wall, and discharging it into the space on each side of the window or door openings. From this description it will be seen that any piece of mortar or fragment of wood, etc., allowed to stick in this dividing space in the course of building operations, would form a bridge which would conduct the moisture to the inner wall, and cause damp patches to appear on the room walls. It is, therefore, of the utmost importance to see that such bridging fragments are avoided. This is done by using a long batten of wood about 2 inches thick, which is laid along the air space, resting on the ties, during the progress of the work, and which is lifted up by the workmen as the wall is built. This at once forms a gauge for the width of the air space, and largely prevents mortar or other rubbish from lodging in the void. Even with this precaution,

however, some rubbish finds its way into the space, mostly falling to the bottom, but sometimes lodging on the connecting ties, from which it must be dislodged by the workmen, as the wall rises if the work is to be efficient in preventing damp. In the case of hollow walls, a damp course in the outer screen walls is evidently useless and unnecessary. The damp course is, therefore, placed only at the bottom of the inner wall. The air space should be extended at least, two courses of bricks below the level of this damp course, which otherwise should be placed as already described. Provision must always be made to drain away the water, which runs down the inner surface of the screen wall, and drops down the space from the ties and gutters over openings. In order that the bottom of the air space may act properly as a conductor of this water to the outlet point, it should be cleaned from the fallen rubbish after the wall is built. For this purpose, openings should be left at intervals at the bottom of the screen wall. These may be subsequently built up or fitted with gratings which at once act as ventilators for the air space, and outlets for the interrupted moisture. The air space in these hollow walls, besides intercepting damp, also acts as an excellent non-conducting layer, which prevents the access or escape of heat, and this renders the house warmer in winter, and cooler in summer, than would be the case if the wall was solid.

A detailed description of the hollow wall is given, because unless properly executed, and from the neglect of apparently unimportant little points, its efficiency is often destroyed. In existing buildings, when walls are damp from exposure to drifting rain, the hollow wall cannot, of course, be easily adopted. In such cases, several coats of paint applied on the *outside* of the wall are effectual for a time, but, of course, require frequent renewal. Portland cement, if trowelled to a fine glossy surface, is efficient and durable, but rather expensive if properly worked.

In some cases, tiles, slates, or shingles are fixed on wood battens, nailed outside the walls. These are effective and durable, and may be made to have a good appearance, but the numerous crevices form a happy hunting ground for spiders, centipedes, scorpions, and other pests, which is a decided disadvantage, and may, in Australia, even prove a danger.

Roof Work.—Damp may arise from defective roof coverings and gutters, etc. The roof coverings most common in Australia are slates, tiles, shingles, and corrugated iron, the latter being by far the most commonly used. In these coverings the points are : Sufficient slope of the roof, and efficient bonding and lap of the pieces forming the covering. In slates and shingles, lap means the cover or over-lap, which the *bottom* of the third course (counting from the bottom) has over the *top* of the first course. That is to say, at that point it takes three courses in thickness to make a complete cover. This is necessary, because each piece forming the coverings is clear of the sides of those adjoining ; in other words, they have no overlap at the sides. Tiles usually overlap at the sides and at the ends, so that two thicknesses make the complete covering, and the same applies to corrugated iron. Damp arising in a house from the roof leaking can be usually traced to the ridges, hips, valleys, gutters, or downspouts. Ridges, as their name implies, are the coverings of the ridge or apex of a roof. In ordinary work they are made of galvanised iron bent to the angle of the roof slopes, and having a large roll or round at the top. In better class work sheet lead is used for this purpose, and in some cases red tile ridging is used because of its ornamental appearance. These may give rise to leaks if the sloping part is too short properly to cover in the joints of the roof covering. Leaks often occur in exposed situations where galvanised iron ridging is used with corrugated iron covering, particularly with roofs of small or flat slope. The corrugations of the

iron, of course, run lengthwise up and down the slopes of the roof, while the lower edges of the ridging, being plain, run horizontally across these corrugations. The ridging thus rests only on the highest parts of the corrugations, leaving openings the full depth of the corrugations between. In wet and stormy weather, the rain is drifted into these openings and so over the top edge of the roof-covering, under the ridging, and into the house. When lead is used for ridging this cannot happen, because the pliability of the lead enables it to be dressed down so as to lie close into each corrugation, so preventing the likelihood of this drift. Metal ridging is usually made in 6 to 10 feet lengths, and is simply overlapped at the joinings. The overlaps should, of course, be turned *from* the prevailing rainy winds. Tile ridging is almost invariably used only on slate or tile roofs, being seldom, if ever, seen on iron or shingles. It should be grooved or overlapped at the joinings, and jointed and bedded in Portland cement. Beyond efficient jointing the important point is to see that the sloping sides have sufficient length properly to cover in the lap of the roof covering.

Hips. Hips, which are the covering of the ridges formed at the outer edges of slopes joining each other, are made of similar material to ridging. The same remarks as to the prevention of leaks apply to them also, but in hip coverings the overlaps should, of course, always be in a downward direction. Sometimes what are called close-cut hips are used in slate-covered roofs. It is done as a matter of appearance, no hip covering being visible, and the slates being cut so as to form a sharp angle at the hip. These are much more difficult to construct, so as to be water-tight, and involve the use of what are called secret gutters, formed under, and hidden by the slates, or of sheets of lead specially shaped, so as to bend round the angle and thus cover the space at the junction of the slates at the angle. These bent lead pieces are also invisible, being fixed under the over lap of the slates.

The details of this method of hip covering are rather difficult to understand, but the method is mentioned here for the purpose of explaining in a general way what is necessary.

Valleys.—Valleys are the coverings of the junctions of slopes at their inner, or re-entering, angles. They are really more or less steeply-sloping gutters. In section they are the reverse of ridges, the central part being lowest, and the sides passing up under the roof covering instead of over it. In ordinary work they are made of galvanised sheet iron, but in the best work are always of sheet lead. The sheets composing valleys are simply overlapped downwards, and the upper edge of the upper sheet should pass well up under the ridge covering. The point of greatest importance in valleys is to see that they are wide enough to pass *under* the roof covering, sufficiently far *up* the slopes of the joining roofs to prevent the possibility of leakage from the points of the covering material at its lower edges, from passing *under* the valley covering, and so into the house. In order to prevent the water which flows down those valleys from the roof covering from spreading horizontally, so as to run over the edges of the valley covering, these edges should be raised slightly. This is commonly done by nailing, what is called, a tilting fillet under the edges of the valley covering, and *over* which it should be dressed or fitted closely. The width of the exposed surface of the valley covering, that is between the edges of the roof covering, should always be wide enough to permit of foot-hold without treading on the roof covering, as otherwise, leaks are very apt to occur through damage done to the roof covering by treading over it.

Gutters.—Gutters are perhaps the most important part of roof work, so far as the possibility of leakage is concerned. It is in these that the whole of the rainfall carried off by ridges, hips, roof coverings, and valleys, is collected, consequently the accumulation of the water renders any defects which may lead to leakage,

much more likely to give rise to serious dampness in the house than would defects in other portions of the roof work. In the order of their increasing importance in this respect, from a sanitary point of view, they may be classified as:—1st, eave gutters; 2nd, wall gutters; 3rd, parapet or valley gutters. Taking these in their order, eave gutters are those placed at the lower edge of roofs which project over, and clear, of the walls under them. Obviously, leakage from such gutters cannot find its way directly into the house, but they may and often do cause damp by the leakage running down the walls and finding its way through to the inside. These gutters are usually made of cast iron, or of galvanized sheet iron, the former being joined by socket pieces cast on the end, formed like the socket of a drain pipe, and are jointed with red or white lead and bolted together. The latter are simply overlapped and soldered together at the joints. Both classes are supported on brackets fixed to what is called an eaves board, and the water should be conducted away from them at sufficiently frequent intervals along their length by pipes called drop horns fixed into the bottom of the gutter, and delivering into the down spout. Sometimes the roofs, to the lower edge of which those gutters are fixed, do not project over the wall, and in such cases the gutters themselves rest partly on the wall and partly project beyond it. Obviously when this is the case, any leakage, particularly next to the roof, is much more serious, as it may find its way directly into the house. In all such gutters, and this applies to boundary wall gutters also, the front or projecting edge of the gutter should always be well below the level of the edge next the roof, so that, in the event of these gutters filling up by reason of a clog in the down spout, or a phenomenal rainfall, they will overflow over the front edge, clear of the wall, the greater height of the edge next the roof preventing any overflow into the house. This point is of much importance. Another arrange-

ment which is desirable in all gutters is, that the discharge opening from the gutter should always be considerably larger in area than the down spout, as a restricted area at this point is often the sole cause of overflow of rain water, in cases where both gutters and down spouts are otherwise quite sufficient to carry off all the water likely to find its way into them. These enlarged discharge openings should be connected to the smaller down spouts, either by a tapered piece, or by the intervention of an enlarged and often ornamental top to the down spout, technically called a rain water head. This is a point frequently lost sight of in ordinary roof work, and it may often happen that a gutter which renders a house damp by its habitual overflow, even in moderately heavy showers, may be made sufficient for its purpose, simply by the introduction of such an enlarged discharge pipe.

The necessity for laying these and all other gutters to a regular and even fall towards the outflow, is obvious without comment.

Wall Gutters.—Wall gutters generally resemble eave gutters, but rest entirely on the wall, and sometimes, as in the case of what are called boundary wall gutters, do not project beyond the line of the wall even at the front upper edge. In such cases, any overflow, even if over the front edge, would be apt to find its way into the house. In these gutters it is, therefore, a prime necessity that they should be of amply sufficient size to carry off the largest quantity of water likely to find its way into them. This is perhaps a matter more for the architect or plumber to decide, but as it will be of service to the inspector to have some general idea of what is likely to be required, the following notes are given. The heaviest shower recorded in New South Wales fell at the rate of 6 inches per hour. As explained under Water Supply, every inch of rainfall over a roof area of one hundred superficial feet means the collection of 52 gallons of water. Gutters must, of course, be of sufficient capacity to carry off the rain as it falls.

The maximum quantity to be carried off by any gutter is therefore obtained, by noting the area of the roof surface drained by that gutter, and ascertaining the quantity represented by rain falling over that area, at the rate of 6 inches per hour. The quantity being in this way arrived at, the size of the gutter necessary can be obtained by reference to any hydraulic table giving the discharge of water by open channels.

Parapet and Valley Gutters.—Parapet and valley gutters call for greater skill in their execution, and a better knowledge of first-class plumbing work, than any of the others. They are occasionally constructed of galvanised iron, but in the best class of work sheet lead is usually employed. Parapet gutters are those situated at the foot of a roof slope, which finishes against a low wall called a parapet, rising to some distance above the level of the bottom edge of the slope. Valley gutter is the term used to denote a gutter situated along the junction of the bottom edge of two sloping roofs. These gutters are constructed in two separate ways, one being distinguished from the other by the term "box-gutter," a form which, as its name implies, is rectangular, or box shaped in section. The other, while flat on the bottom, has its sides formed by the slope of the adjoining roofs in the case of the valley gutter, and the slope of the vertical wall in the case of the parapet gutter. In all these gutters, particularly when lead is the material employed, the all-important point is, so to construct them that the inevitable expansion and contraction, due to changes in temperature, will have free play; that is to say, that none of the parts, wherein the water is collected, are rigidly fixed, as the effect of this would be, sooner or later, to cause the material to crack, and so create leakages and damp. In order to do this, the material must be laid in sections of a length which will permit it to slide along the surfaces on which it rests, as it expands or contracts, without creasing up, or buckling as

it is called. These lengths depend on the rigidity of the material of which the gutter is made. Thus, iron being more rigid, can be used in longer lengths than lead, which being a soft and ductile material, would buckle and ultimately crack, if the length of the section exceeded from 7 to 10ft. In long gutters of these classes, shallow steps, technically called drips, are formed to unite the separate sections, and in inferior work, it is at these drips that leaks are likely to occur. The drips should be at least from one and a half to two inches high, if the passage of the water up under the overlapping gutter material is to be avoided. The box form of gutter is considered the best, as in it the free expansion of that part of the gutter wherein the water collects, can be more thoroughly secured. In this form the bottom and sides are made in one piece of lead or iron, and the sectional area of this part must be large enough to carry off the maximum flow. The upper edges of this box part are protected from the weather by means of separate sheets of the metal, called aprons, hanging down over them, passing up well under the roof covering, on the roof side or sides, or fixed firmly at their upper edge into a horizontal slot or channel cut into the face of the stone or brick work of the parapet, this channel being afterwards filled in with cement, so as to render its junction with the apron, water-tight. In this way, it will be seen that the box part which carries the water, is left free to expand and contract, and is so secured against cracking and leakage, while the apron part, over which the rain merely trickles, is the only portion of the construction, of necessity rigidly fixed. In parapet gutters, the possibility of damage, arising from the chokage of down spouts, is guarded against by the provision of what are called over-flows. These are openings through the parapet at intervals, situated below the level of the top edge of the box part of the gutter, and intended to allow the water to escape through them, before it rises to the level of the upper

edge of the box part. In these gutters the enlargement of the outflow pipe, before referred to, is obtained by the construction of what is called a cess box. This consists of a deep box, formed in the gutter, from the bottom of which the pipe leading to the down spout passes. Sometimes one over-flow pipe, of large size, is provided in these cess boxes, instead of a number distributed along the gutter. The discharge pipe at the bottom of the cess box should always be provided with an open, hemispherical grating, to prevent its stoppage by leaves, etc., washed into the box from the roof gutters, and in places where leaves are likely to accumulate on the roofs, it is desirable that the gutters themselves should be protected by coverings of stout wire netting.

There are other points in roof coverings where leakages may occur, such as, around chimneys coming through the roof, and at skylights, &c., but it is impossible in the space here available fully to describe the somewhat complicated details of the plumbing work there required. It will be sufficient to say that the principle of constructing all parts where the storm water is collected and conducted away, in such a manner as to allow for the free expansion and contraction of the material used, and to conduct all flowing water over the meetings of the individual parts by means of overlaps, or of aprons placed with the direction of the flow, are the main points to be attended to in this class of work. For this reason soldered joinings are to a large extent inadmissible in all roof work of this description.

Down Spouts.—Down spouts wherever possible should be fixed on the outside of the walls, and it is better if they can be so secured in place, as to allow a space between the wall and the pipe. These may cause damp chiefly by the escape of water from their joints (in the event of chokage) which, running down the walls, is so apt to soak through them. For this reason down spouts should be of ample size, and have free outflow at their lower end, so as to prevent as far

as possible any lodgment in them of rubbish washed down from the roof.

Floors and Spaces under Floors.—The floors of ordinary dwelling houses are usually constructed of boarding laid on supporting timbers, called in the case of ground floors sleepers, and in upper floor joists. In ground floors the sleepers should always be raised well above the ground level. It is desirable that the ground surface should be covered with an impervious coating, such as tar, concrete, asphalt or cement, so as to protect the house from the access to it of damp from the soil, or of ground air. The expense, however, often prevents this being done, but when the soil is damp, or where the house is built on what is called "made" ground, such a coating is absolutely necessary, if healthful conditions are required. In every case these spaces should be thoroughly ventilated by means of air bricks, as they are called, freely inserted in the outer walls, and by openings formed in any crossbearing or partition walls within the building. These openings should be placed so as to secure the freest circulation of air through every corner of this under-floor space. This ventilation is the more necessary where the ground surface is uncoated, as it largely prevents the access of moist vapours, and of ground air from the soil, into the rooms of the house. Under-floor ventilation secures this by interposing a reservoir or layer of pure air between the surface of the soil and the house floors. Wood flooring when used should be close-jointed, so as to prevent the accumulation of dirt between the edges of the boards, and it should be smooth and close-grained, in order to permit of ready and thorough cleansing. For the same reason the skirting boards round the walls should fit close to the floor, and where this is not the case, strips of wood of triangular section should be fixed, so as to fill the angle between the floor and the skirting board, which will at once close up the spaces, and prevent the collection of dirt in the angles, by facilitating

sweeping. In view of the recent introduction and spread of plague in the colony through the agency of rats, it becomes a matter of much importance to prevent the access of those rodents into our houses. Defective drains and insanitary fittings, no doubt, provide their most ready means of access, and that matter will be dealt with in the next chapter, but the provision of a coating over the surface of the soil under the house, and the protection of all openings to the under-floor space, by means of grated air bricks, would obviously provide an effective bar to their entrance.

Special flooring and wall covering is required under the Acts dealing with abattoirs, dairies and certain noxious trades. Under the Noxious Trades and Cattle Slaughtering Acts of 1894, the following regulations have been issued regarding the construction and arrangement of premises licensed as slaughter houses, within the municipality.

"Slaughter-houses.—On all registered premises there should be a killing-house, and one or more stock yards or pens; the killing-house should be well-lighted and ventilated, at least two of its sides being open to direct communication with the outer air, and no killing-house should be erected within a hundred feet of any dwelling-house.

"If the killing-house is built of stone or brick, the inside of the doors, to a height of 6 feet, shall be covered with galvanised iron, and the walls, from the floor for a height of 6 feet, shall be covered with smooth cement, or some similarly impervious material, capable of being washed clean with water. If constructed of other material, the whole of the interior for the same height shall be covered with galvanised iron.

"All wood work in the killing-house, not covered with galvanised iron, shall be covered with a layer of paint, tar, or lime wash. The floor of the killing-house shall be of concrete or other approved impervious material, capable of being ready and thorough cleansing with water, laid upon a suitable bottom, and with a sufficient slope to allow of effectual drainage. The stock yards and pens shall be so paved as to admit of a smooth surface, and shall be so drained as to permit of effectual cleansing.

"A killing-house shall not have any rooms or lofts thereover, nor contain any water-closet, privy, urinal, or stable, and no water-closet, privy, urinal, cesspool, or stable nor any room,

used for living or sleeping in, shall be connected with, nor ventilated into any killing-house.

"If the slaughter-house is drained by connection with a public sewer, such drain should be properly trapped, and protected with a grating, of which the bars shall not be more than three-eighths of an inch apart.

"Every slaughter-house shall be provided with an adequate supply of water for cleansing and other purposes. The water used for dressing the carcases shall be free from impurities. Proper arrangements shall be made for a supply of hot water for cleansing utensils and appliances. There shall be a water-tank within every slaughter-house premises; it shall be placed where the Local Authority shall direct. The bottom of the tank shall not be less than 6 feet above the floor, and the tank shall be properly covered."

The model by-laws issued by the British Local Government Board contain certain provisions not included in those above quoted, viz. :—

"The slaughter-house should not, in any part, be below the surface of the adjoining ground. The approach to the slaughter-house should not be on an incline of more than 1 in 4, and should not be through any dwelling-house or shop."

The provisions in these Model by-laws with regard to drainage are more explicit than those above quoted. They state :—

"The slaughter-house should be well-paved with asphalt or concrete, and laid with proper slope, and channel towards a gully, which should be properly trapped and covered with a grating, the bars of which shall not be more than three-eighths of an inch apart."

In regard to this, Dr. Reid makes some excellent suggestions, explanatory of the clause quoted. He says: "All slaughter-houses, cowsheds, and stables must be disconnected from the drains—that is, no trap should be placed within the buildings. The floor should have a slight fall from all sides towards one point close to the wall, through which a pipe should be carried to a gully on the outside."

Cowsheds and Dairies.—Under the Dairies Supervision Act of 1886 the following provisions regarding the floors and drainage of bails, cowsheds, dairies, etc., have been issued :—

"The flooring of bails cowsheds, dairies, etc., must be made of smooth impervious material, such as stone, brick, concrete, mineral-asphalt, or the like. These must be laid on a good bottom, and all joints and cracks filled with impervious material so that no liquid can leak into them. These materials are to be preferred in every situation; but in bails, wood may be used. This must be of the hardest sort available, in squared planks not less than 3in. thick. The planks must be accurately fitted to each other, solidly held together, and so caulked that no liquid can leak into them. All floors must be slightly inclined so as to throw off all water and stalings. Bails and milking-sheds should be thoroughly well lime-washed once in three months, and as much oftener as may be necessary to keep them clean and sweet. Liquid filth should be conducted from sheds and bails by a well-constructed gutter. This should be open so that it can be swept down daily, and it should have an even fall from its beginning in the milking shed, or at the bails, to its termination. The milking yard should have a dry and solid surface. It may need to be underdrained, metalled, and rolled, or paved, or tarpaved, and it must be graded to a gutter. The approaches to milking yards should also be formed, and gutters should be cut so as to prevent water from standing near the yards. The dung-heap should be as far as possible from the bails and milk room. All roofs should be furnished with guttering and spouting to lead off rain-water to tanks, etc., or to well-laid open gutters, so as to prevent the accumulation of pools of stagnant water.

"Every dairy premises must have a milk room to be used for separating, or for straining and cooling the milk, or for storing vessels and utensils when they are not in actual use. It must not be under the same roof as, nor in communication with, any bail, stable, or fodder store. It must not communicate with any living room, nor must it have any room over or under it. It should be detached, but the Local Authority

may give permission to build it as a "lean-to" against the blank wall of some other building. It should be placed as far as possible from bails and yards, and must be at a safe distance from fowl yards, drains, privies, dung heaps, pigstyes, and other possible sources of contamination. As one object of this room is to provide a place free from the dust of yards, sheds, bails, etc., where the vessels may be washed and kept clean, a boiler should be provided close by, so that hot water for washing-up may be got without going to the kitchen or washhouse. Milk or milk-vessels must always be kept quite apart from the dwelling house, and the milk room must not be used for any other purposes than those already named. The milk room must be floored with some non-absorbent material. It must be well lighted and well ventilated. Its windows and doors should be fitted to keep out flies and dust. There must be no direct connection between the milkroom and a sewer, and it should be kept cool and shaded. Pigstyes should not be less than fifty yards from any dwelling, milk room, bail, or yard.

"A good supply of water is essential on dairy premises, and, wherever possible, they should be connected with the public water-mains. Wherever this is possible all underground tanks and wells must be closed. Water troughs in yards and paddocks should have a waste hole at the bottom so that they can be easily emptied and regularly cleaned. The vicinity of the troughs must be paved or otherwise prevented from becoming soft or muddy. Wells should not be sunk near any dwelling, yard, bail, privy, dung-heap, fowl-yard, pigstye or other source of contamination nor in any frequented place. They must be securely covered and fitted with a pump, and they must be protected by a wall or coaming to prevent inflow of surface water during rains. Access of cows to impure water, as in drains, etc., must be prevented by fencing, etc. It should be noted that if the water is found to be polluted and unsafe, the dairyman

is required to find a fresh source, failing which, his registration may be cancelled. If dairy premises stand within reach of public sewers, they must be connected with them, in that case they must be furnished with water-closets. When no public sewer is within reach, dairy premises must be provided with pail-closets, which must be emptied not less frequently than once a week. When the premises are out of reach of the public scavenger, the pail must be emptied by the householder. The contents should be dug into the surface soil and turned over with the spade, so as to be mixed with the earth between the surface, and not more than nine inches below it. They are not to be simply tipped into a hole and buried in a solid mass. A kitchen garden may be a suitable place; but any place is unsuitable where surface waters may wash the night soil into waters which may be used for drinking by man or animals; so also is any place near a well or tank, etc. Any spot thus used for burying should not be used again for at least a month. Cesspits are not allowed on dairy premises. If they exist they must be first emptied, and then filled up with clean earth level with the surface of the ground, before registration is granted."

These regulations are in the main founded on those in force in Britain, but the following clauses from the British Local Government by-laws regarding dairies may be quoted:—

"Ventilation of all buildings used as cowsheds or milk stores shall be by means of openings or windows in the walls on two opposite sides of the building, or in the wall on one side and the roof, such openings or windows having direct communication with the external air. If the windows or openings are made to close, then other means must be provided for ensuring constant ventilation. There must be at least 800 cubic feet of air space provided for each head of cattle. The floor of every building must be constructed with a fall to a channel which shall discharge itself over a properly trapped drain *outside* the building. There

must be an adequate water supply of good quality, and any receptacle used for storing water must be emptied and cleansed at least twice a year,—oftener if necessary,—be easy of access, properly constructed, and furnished with a good fitting cover. The walls and ceilings are to be lime-washed at least twice every year, unless the walls are painted, or otherwise where the material would render limewashing unsuitable.

“As regards the walls and ceilings of milkshops and milk stores, the same regulations are made; but the operation must be performed at least three times in every year.”

“Further regulations with regard to milk shops and milk stores are:—“No milk shall be stored in any building in which there shall be any untrapped drain, or where the milk shall be exposed to infection or contamination. There shall not be within a place used for storing milk, any opening to the drain or communication with a w.c. or privy.”

Premises used for Noxious Trades.—Under the Noxious Trades and Cattle Slaughtering Act of 1894, the following regulations apply to premises where fat-melting, fat-extracting, bone-boiling, bone-grinding, blood-boiling, blood-drying, glue-making, or soap-drying is carried on:—“All floors on which any process of the above-mentioned trades is carried on, shall be properly covered with a layer of concrete, or other approved material, laid upon a suitable bottom, shall have a proper slope towards a channel or gully, and shall be effectually drained by adequate drains, so discharging as not to be a cause of nuisance. Every drain shall be properly trapped, and shall be protected with a grid, of which the bars shall not be more than $\frac{3}{8}$ of an inch apart. The internal surface of the walls and every floor or pavement shall be kept in good order and repair so as to prevent the absorption of any liquid filth or refuse or any noxious or offensive matter. After being thoroughly cleansed by scraping or other means, they shall be thoroughly washed with hot lime-wash four times at least every year. All premises

shall be provided with apparatus or appliances capable of effectually destroying noxious or offensive vapours, gases or effluvia, arising in any process or from any material residue, or other substance, which may be kept or stored upon them. No liquid or waste matter shall be allowed to leave the premises until they have been so purified as not to be a cause of nuisance.

In regard to pig-keepers and poultry-farmers, it is stipulated that :—"Every pig-keeper or poultry-farmer shall have on his premises one or more boilers with a fire-place of approved construction ; they shall have a cover by which they shall be closed air-tight, and they shall always be kept so closed except when being filled, or emptied, or cleaned ; every such boiler shall be furnished with a pipe for the escape of steam, and this pipe shall be so arranged that the steam escapes in the ash-pit below the furnace. Pigs shall be fed in enclosed yards, which shall be floored with brick or other approved impervious material, set on a good bottom, and having a proper fall for drainage. Feeding troughs in sufficient number shall be provided. Such portions of the buildings or premises as may be indicated by an inspector under Part I. of the Act shall be kept thoroughly lime-washed to the satisfaction of the inspector."

The following regulations are made with regard to the construction of premises where gut-scraping is carried on :—"All materials shall be collected in approved receptacles provided with air-tight lids, which shall be kept closed except when being filled. A separate room from that in which salting or spinning is done must be provided for scraping. Floors shall be properly covered with a layer of concrete, or other approved impervious material, laid upon a suitable bottom, and having a proper slope towards a channel or gully, and adequate drains discharging, so as not to be a cause of nuisance. The drains to be properly trapped and protected by a grid with bars not exceeding $\frac{3}{8}$ in. apart. The walls of the

scraping or cleaning room shall either be cemented or protected with plain iron smoothly laid and carefully jointed to a height of 6 ft. from the floor level; uprights, posts, etc., shall be protected in a similar way, as circumstances will permit, and as any Inspector under Part I of the Act shall direct; and such portions of the buildings or premises, as indicated by the Inspector, shall be lime-washed to his satisfaction, and the premises shall be well ventilated by such openings as shall be required by the Inspector. All angles and corners must be smoothly rounded so as to prevent filth from lodging. An air-tight metal receptacle has to be provided for all solid wastes, and its contents must be removed at least once in 24 hours."

Factories and Shops.—The following regulations as to the buildings in connection with factories and shops appear in the Factories and Shops Act of 1896, or in the regulations thereunder:—“The inside walls, ceilings, passages and staircases, whether plastered or not, shall be varnished or painted with oil, at least once in every seven years, or lime-washed or washed with some liquid approved by the Inspector, at least once every 14 months, and in the case of a bakehouse situated in a municipality once every six months. Painted or varnished surfaces must be washed with hot water and soap, at least once every 14 months. The Inspector may order walls, ceilings, passages, and staircases to be painted, varnished, lime-washed, or washed more frequently, if it appears to him necessary. If the walls or passages are papered, they need not be varnished, painted, or washed, but shall be re-papered when directed by the Inspector. Under the Act, these clauses do not apply to certain specified buildings, and in certain special cases the Minister may exempt particular factories or shops from these regulations. Under this Act all dangerous machinery must be fenced and also the openings at hatchways, elevator wells, and soon. Where ordered, doors must be made to open outwards, and

in factories three or more storeys in height, in which persons are employed above the 2nd storey, a certificate must be obtained from the Inspector, that the factory is provided with such means of escape in case of fire for the persons employed therein, as can reasonably be required under the circumstances of each case. The provisions as to cubic space, ventilation and chimney flues, have already been referred to in the previous chapter. Every factory and shop must be provided with proper closet accommodation in the proportion of one closet at least for every 20 persons employed, and separate accommodation and approaches thereto must be provided where persons of different sexes are employed. But where not more than two employees are of one sex, the majority of employees being of the other sex, separate accommodation is not required, if in the opinion of the Inspector the same is suitably provided in adjoining or adjacent premises. If the nature of the work necessitates the females employed changing their dresses, a suitable dressing room must be provided. When required by the Inspector, every factory and shop shall be fitted with a $2\frac{1}{2}$ -inch hydrant, hose, branch and nozzle inside the main entrance, and at top of each staircase, and be supplied with such number of buckets as the inspector may determine, and of such pattern as he may approve, and be kept (filled with water) at all times, on each floor of such factory or shop." The following are special clauses regarding bakehouses :—"No place on the same level with the bakehouse, and forming part of the same building, shall be used as a sleeping place, unless it is effectually separated from communication with the bakehouse by a partition extending from the floor to the ceiling, and has an external glazed window of at least 9 superficial feet in area, of which at least $4\frac{1}{2}$ superficial feet are made so as to open for ventilation. No drain pipe for carrying off faecal or sewage matter shall have an opening within the bakehouse ; and no earth or water-closet, cesspit, urinal, or ash-

pit, shall be within or communicate with the bakehouse. Any cistern, for supplying water to the bakehouse, shall be separate and distinct from any cistern supplying water to a water closet."

In certain classes of factories and shops, the Minister may, in writing order that a suitable room be provided when meals are to be taken, and prohibit the taking of food in any room where work is being carried on.

At the discretion of the Inspector, special ventilation by means of fans, or other mechanical power, must be provided in special cases, as for instance where grinding, glazing or polishing on a wheel, or other process is carried on, whereby dust is generated which is inhaled by the employees to an injurious extent, or when atmospheric humidity is artificially produced, whereby the health of the employees is, or may be, injuriously affected.

Sitting accommodation conveniently situated for their use, must be provided in the proportion of one seat for every three females employed.

Building Regulations under Public Health Act.—Under the Public Health Act of 1896, "If the Board of Health, after causing due enquiry to be made, is of opinion that it would be prejudicial to health that any land should in its then condition be built upon, the Minister may declare that the land shall not be built upon until the measures specified in a document deposited in the office of the Local Authority and open to public inspection shall have been taken, or till the notice is revoked by, the Minister, and for the purpose of such enquiry any person authorised by the Minister or the Board in that behalf may enter any land, and dig holes therein and remove the soil thereof."

Construction of General Buildings.—Buildings erected in Sydney are under the provisions of the City of Sydney Improvement Act of 1879, which is defined as an Act to make better provision for the construction of buildings, and for the safety and health of the

inhabitants of the city of Sydney. The following provisions refer more particularly to matters of sanitation. Dwelling-houses are not permitted to be built fronting a lane less than 20 feet wide. The height of a building is defined as the height from the top of the footings to the top of the wall. The number of storeys is to be counted from the foundation upwards, and the space between the top of the footings and the level of the lowest floor is not to be counted as a storey, unless the height exceeds 6 feet. The soil is to be removed for a depth of at least 9 inches below the under edge of the joists forming the basement or ground floor, and this space must be ventilated to the satisfaction of the surveyor, except where the space is filled in solid with concrete, on which tiles, boards, or cement may be laid to form floor. No materials that have been used in the construction of any cesspit, drain, or sewer, or that may be considered by the health officer dangerous to health, shall be permitted to be used in the erection of any building. Rooms, not being store-rooms or bath-rooms in any dwelling-house, "shall be ventilated by an opening communicating with the external air, or in any other manner approved by the surveyor and health officer, and all window-sash casements shall either be double-hung, made to slide horizontally, or hung with hinges, to the satisfaction of the surveyor." Not more than one floor of rooms is allowed in the roof of any building, and these rooms must not be less than 7 feet 6 inches high, "except the sloping part of such roof, and such sloping part shall not begin at a less height than 3 feet 6 inches above the floor. Other rooms must not be less than 8 feet high from floor to ceiling." In regard to privies, the following is stipulated: "There shall be a cesspit to every privy, and such cesspit shall be constructed of good, sound bricks, bedded, jointed, flushed, and grouted in cement." The walls are to be 9 inches in thickness, the floor two courses of brick on edge, of such shape as the surveyor may direct.

The interior dimensions, when completed, are to be not less than 4 feet x 3 feet 6 inches wide by 4 feet deep, measuring from the bottom of the cesspit to the edges of the joists forming the floor, and the walls must be carried up to a height of at least 6 inches above the highest point of the surface of the surrounding ground. The inside of the brick-work to be rendered and floated, at least $\frac{5}{8}$ ths of an inch thick, in English Portland, or other cement approved of by the surveyor, mixed with sand, in proportion of 1 to 2, and made perfectly water-tight. No pipe or drain of any description to be connected with any cesspit. Every privy and closet to be enclosed with improved materials, have a rain-proof roof, a hinged door, with latch and bolt, a floor, a riser, and a seat, and shall be lighted, ventilated, and screened from public view, and built in every respect to the satisfaction of the surveyor.

The Model Bye-Laws issued by the British Local Government Board contain many important sanitary provisions regarding air-space structure, drainage, and refuse disposal. Under these, new buildings must have provided in front "an open space which shall be free from any erection above the level of the ground (except a portico porch or light projection from the building, or any gate, fence or wall not exceeding seven feet in height), and which measured to the boundary of any lands or premises immediately opposite, or to the opposite side of any street which such building may front, shall extend to a distance of 24ft. at least." Air spaces are also required at the rear of such buildings as follow: "An open space exclusively belonging to such building, of an aggregate extent of not less than 150 square feet, and free from any erection thereon above the level of the ground except a water-closet, earth-closet or privy, and an ashpit." The distance across such open space from every part of the building to the boundary must not be less in any case than 10ft.; but if the height of the building be 15ft. the distance shall be

15ft. at least; if the height be 25ft. the distance to be 20ft. at least, and if the height be 35ft. or over the distance must be 25ft. at least. In this case the height of the building is measured as from the level of the ground, upwards to half the vertical height of the roof, or to the top of the parapet, whichever may be the higher. Every habitable room of such building must have one window at least, opening directly to the external air, and one-half at least made to open so that the opening may extend to the top of the window. The area of such window or windows, clear of the sash frame, to be equal at least to one-tenth of the floor area of the room. Every habitable room which has an outer fireplace and chimney flue must be provided with a special and adequate means of ventilation by an aperture and air-shaft, having an unobstructed sectional area of at least one hundred square inches. Damp sites must be drained, and basement rooms be at such a level, that they can be drained into the upper half of the sewer. Earth-closets must have a sufficient supply of dry earth, and if a fixed receptacle is provided it must have ready access for the purpose of cleaning out, and the capacity must not exceed 40 cubic feet, and it must be non-absorbent and water-tight, and the bottom must be at least 3 inches above the level of the surface of the ground adjoining. Privies must be at least 6ft. from any occupied building or public building. Privies with movable receptacles or nightsoil pans (as they are called here) must have a flagged or asphalted floor at least 3 inches above the level of the adjoining ground, and the whole of each side of the space between the floor and the seat to be constructed of flagging, slate or good brickwork, at least 9 inches thick, rendered in good cement or asphalted. The movable receptacle or pail must not have a capacity exceeding two cubic feet. Ash-pits must be placed 6 feet at least from any occupied room or public building, and must be of a capacity not exceeding in any case 6 cubic feet, or of such less

capacity as may be sufficient to contain all dust, ashes, rubbish and dry refuse which may accumulate during a period not exceeding one week, upon the premises to which such ash-pit may belong. It shall be constructed of flagging, slate, or good brickwork at least 9 in. thick, rendered inside with good cement or properly asphalted. The floor at least 3 inches above the surface of the ground adjoining, and covered with flagging or asphalted. It must be properly roofed, and must not communicate with any drain.

CHAPTER X.

SEWAGE AND REFUSE DISPOSAL.

"In the course of 24 hours the lungs of a full-grown man discharge more than 200 grammes (28 ounces) of carbonic acid, whilst the combined dried-up urine and faeces voided during the same time amount to only about 90 grammes (.315 ounce). About nine-tenths of the daily excretion takes place by way of the lungs, and is disposed of involuntarily by aerial carriage, and only the remaining one-tenth is left for man to dispose of by artificial means, and to manage or mismanage, as the case may be. This one-tenth of the body waste, which is left for man to get rid of by artificial means, is not the sole constituent of that complex compound called sewage. Sewage is a highly complex liquid, and contains a large amount of fluid and soluble matters, which are liable to rapid chemical change, and which give off volatile products. A large proportion of its offensive matters, is, of course, human excrement, discharged from water-closets and privies, and also urine thrown down sinks and gully holes. Wanklyn and Cooper reckon that .6 grammes of material of excretal origin exists in each litre of sewage. In addition to this excretal matter, we have the water from the closets, and the waste water from kitchens, containing vegetable, animal, and other refuse, and that from wash-houses, containing soap and the debris from soiled linen. The waste waters from the house form a very complex liquid, which is so impure that it is to all intent and purposes sewage, and is to be dealt with as such, for these waters usually contain urine, which, along with animal and vegetable refuse, will undergo decomposition. Soap is not an excretal matter, but still it plays an important part in sewage, and con-

tributes at least 5 grammes per individual per day. The effect of soap upon sewage is to contribute an alkali, to favour the setting up of fermentation, and the bringing about of those changes which are involved in the production of sewage. Stables, cowsheds, street drainage, also assist to swell the complexity of sewage, and to render difficult its ultimate treatment, but the worst factors of these difficulties are those industrial wastes which come from the refuse of manufactories. Typical sewage, therefore, is a complex liquid, consisting of the day's visible excreta, mixed with the wastes mentioned, and 150 litres of water per individual of the population. The reaction of fresh, healthy faecal matter, voided by persons using a mixed diet, is acid, and it only slowly becomes alkaline from the production of ammonia through decomposition. If solid excreta is heated, a large quantity of inflammable gas is evolved, which is for the most part carburetted hydrogen; and when solid excreta begin to decompose they give off very foetid organic substances, which pass into the air. According to the old Mosaic law, the dwellers in the camp were enjoined to bury their excreta beyond the camp boundary, and in this way they allowed the soil to exercise its powers of nitrification, and to resolve the harmful waste products of man into innocuous compounds, which were of use to plant life. The closer settlement of man on the soil, brought about, as has been mentioned at the beginning of this text book, the necessity for devising some means, whereby these waste products, (which would then have, from their quantity, overtaxed the purifying powers of the soil), could be speedily got rid of in a manner likely to result in the least harm to the community. The Romans devised the water carriage system, as exemplified by the *Cloaca Maxima*; but after the fall of this empire civilization went back for a period of years, and sanitation was forgotten and had to be again discovered. Gradually, however, it was thrust upon men, through ever recurring epidemics of disease,

that some steps must be taken for self-preservation, and thus slowly step by step we have arrived at our present knowledge of the science of hygiene. The methods of sewage disposal and removal resolve themselves into two classes—

1. THE DRY METHOD.

2. THE WATER METHOD.

What is called the dry method for the treatment and disposal of the liquid and solid waste matters arising from inhabited places, may conveniently be classified under three heads—1st, nightsoil; 2nd, slop water; and 3rd, garbage. In this connection it is well first to note that the opponents of what is called the water carriage system, as opposed to what is known as the conservancy system, have too often lost sight of the fact that slop waters are practically almost as impure as is the average water-carried sewage. It follows that a conservancy system which, as is usually the case, provides only for the disposal of nightsoil, makes no proper provision for the treatment and disposal of the much larger quantity of nuisance-producing liquid known as slop water. This liquid is much too impure to be carried off without offence in the ordinary storm water channels, and its proper disposal, therefore, involves the provision of sanitary fittings, drains, sewers, and outfalls, which would be practically as costly, as if used for the water carriage of nightsoil in addition. If, then, a sufficient, safe, and inoffensive system of nightsoil *and slop water* disposal, is to be initiated, the much-urged economy of the conservancy system vanishes. Under existing conditions, however, in many cases the conservancy system is the only one immediately available. It is, therefore, necessary for the Inspector to understand how that system, together with the separate disposal of slop waters, can best be carried out with the minimum of danger, offence, and inconvenience to the householder and to the general public.

Night Soil.—What is known as the conservancy system implies the collection and disposal of the night soil solids, and liquids, either by themselves or mixed with the contents of the ash-pits, as in the earlier methods, or well-sifted ashes, dry earth, or other dry deodorent materials as in the more modern appliances. The mixing of nightsoil with the moist, offensive, and often decaying matters found in the old style of ash-pit or midden, simply aggravated the inevitable objectionable conditions arising, where such a mixture was stored on the premises for an indefinite period. These conditions are largely dependent for their offensiveness on the presence in excess of moisture, and when it is considered that the old-fashioned ash-pit or midden, was simply a hole dug in the more or less porous soil and being roofless, exposed to every shower that fell, and further that sometimes it was not cleaned out for years, the state of matters so arising, may perhaps be imagined, but hardly described. Needless to say that such an arrangement is now entirely condemned; the ash-pit or midden should be quite separate, made of small dimensions, covered from the weather, and watertight, and the nightsoil is kept apart, by preference in small movable receptacles, and where possible mingled with sufficient dry material to absorb the moisture and reduce the mixture to the consistency of ordinary garden soil. Sometimes, especially when the nightsoil of a populous district has to be dealt with, the cost and difficulty of obtaining a sufficient quantity of dry material to mix with it, makes its use prohibitive, and it may be added that, unfortunately, even where this dry material can be provided, the householders are often too careless or indifferent to make use of it for this reason, the collection of the crude nightsoil in small movable receptacles, has been largely adopted in Australia, and is generally known as the pail system. In this system also, there is a right and a wrong way in which it should be carried out. Even when arranged for in the right way, it must

always be more or less objectionable to the individual user, but not at all to the general public. But when applied in the wrong way, as it unfortunately is in the majority of our Australian towns, where this system is in use, it forms a hideous nuisance and offence not only to the individual user, but to the public at large.

Before proceeding to describe the two last mentioned methods, which are known respectively as the dry earth, and the pail closet systems, a short reference may be made to the privy-pit or cesspit method. In this, the privy seat was placed directly over a large pit, often 3 to 4ft. square, and 4ft. or more deep. This pit, also, was frequently merely a hole dug in the soil, sometimes loosely bricked round the sides, to keep the earth from falling in, and *occasionally* having a loose unjointed brick bottom. These abominations being of large capacity, were emptied only at long intervals of time. If the soil were porous, so that the horribly impure liquid portion could soak away into it, polluting the soil and possibly the well water forming the house supply, they were often never cleaned out at all—these accumulations of corrupting matter should of course always be condemned, and the various regulations mentioned in the foregoing chapter indicate how this class of closet should be constructed, where, for any reason, they must be adopted; and also show in what special cases they are not permitted at all.

Dry Earth Closet.—The principle underlying the action of the dry earth closet, depends on the bringing into operation of the earth organisms, which in natural soil give rise to the resolution of organic matters into harmless gases, and inorganic and, therefore, non-putrescible bodies. This breaking down is held by some to take place in two stages: first, the de-nitrifying stage; and second, the nitrifying or oxidising stage. There seems no doubt, that the first process is associated with what is commonly called putrefactive change, during which the well-known

offensive odours arising from organic liquids and solids, which, in popular language, "have gone bad," appear. The second stage is unaccompanied by offensive smell, and this method is therefore to be aimed at whenever possible. Whether those two stages take place independently in purification by soil, or not, is still a debatable question, but there is no doubt that, in the most recent bacteriological methods of sewage treatment, as they are called, the whole charge, from the complicated organic matters to the ultimate nitrification, or stage of complete purification takes place without any perceptible offensive odour—if, therefore, these two stages exist in such methods, they must follow each other so closely, or modify each other in some way, so that the characteristic odour of putrefaction is altogether lost. One thing we do know, namely, that an excess of moisture, accompanying organic matters, such as is the case in ordinary untreated night-soil, gives rise to highly offensive putrefactive change, which takes place in this climate in from 12 to 24 hours, according to the season and the conditions of temperature and moisture. On the other hand, the same nightsoil, if mixed with sufficient dry material to distribute the excess liquid so as to reduce the moisture of the mass to about that found in ordinary good garden soil, will rapidly break up the organic matter, and cause it to disappear or be assimilated, without any apparent offensive odour.

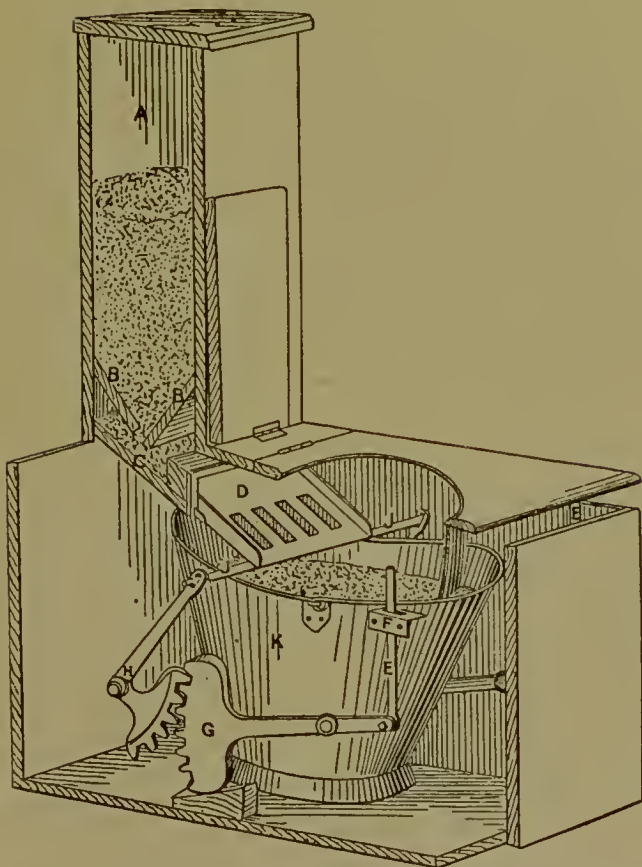
It is by making use of this well-known fact that the undoubted success of the dry earth closet is due. In the earlier forms of this closet, dried garden soil was used. The apparatus, as originally made, consisted of a box containing a pail placed closely under the seat. The back portion of this enclosure was continued 2 ft. or so upwards, and formed a smaller box containing the store of dried earth. The seat was hinged, and rested on a lever which actuated a scoop-sprinkler at the bottom of the dry earth box.

The weight of the user pressing the seat down on this lever slid the scoop backwards, and allowed a charge of the dry earth to fall into it. When the weight was removed from the seat, the lever pushed it up, at the same time bringing the scoop forward with a jerk, and so distributing the charge of dry earth over the surface of the material in the pan. The illustration, No. 19, shows the mechanism clearly. It will be seen that in this appliance the distribution of the earth is perfectly automatic, which is a very necessary provision for general public use. This apparatus is, of course, somewhat more costly than would be a simple pail closet, with a separate receptacle for earth and a hand scoop, which would be equally efficacious if regularly used; but the difficulty is, that the public can seldom be persuaded to take the trouble to use it regularly.

Of course the mechanism can be and often is varied in different forms of this apparatus. Sometimes the earth-distributing apparatus is brought into action by a handle or pull which the user is expected to actuate. At other times where ranges of these closets are fitted up side by side, a single handle, which is actuated by an attendant at intervals as may be necessary, distributes a charge over each pail of the range in one action; but the object is the same in each case, and the method when properly attended to is undoubtedly successful, not only in preventing nuisance but by presenting to appearance only an unobjectionable earth surface, instead of the unpleasant conditions apparent when the uncovered and semi-liquid body of nightsoil is left exposed to view as in the ordinary pail-closet. For this reason, and also because of the unobjectionable appearance of the contents on being manipulated in removal, a good dry-earth closet may be described as furnishing by far the least repulsive application of the conservancy system. In some arrangements of this system an effort is made to separate the liquid from the solid matter. This is sometimes done by providing a sort

AUTOMATIC EARTH CLOSET

FIG. 19.



DESCRIPTION.—K, pail receptacle ; E, rods actuated by hinged seat ; F, guide to rod E, fixed to side of casing ; G, geared weighted lever, pivoted to side of casing ; H, geared connecting lever to carrying bar J and distributing scoop D, pivoted to side of casing ; A, the receptacle for dry earth ; BB, guides ; C, bottom of earth receptacle and guide for scoop D.

The action is as follows : The weight of the user pressing on the hinged seat pushes it down and with it the rods E, so lifting the weighted geared lever G, and causing the distributing scoop D to be pushed back under the opening at the guide plates B. On the user rising, the weight being removed from the seat, the weighted lever, G, falls, so bringing forward the distributing scoop D with a jerk, and scattering its charge of dry earth over the contents of the pail.

of shoot under the front part of the seat, whereby the greater part of the urine is conducted to a separate vessel containing absorbent material. At other times the pail is made with a perforated bottom, and placed over a receptacle also filled with absorbent material. This enables any excess moisture to drain away from the material, so enabling the remaining matter in the pail to be more thoroughly dried by the earth, so that a smaller quantity will produce the requisite effect. This separation principle is applied in the O'Brien closet, which has been successfully introduced in the N.S.W. public schools. Another method of drying the nightsoil by the separation of the liquid, has been introduced by some of the inland districts in Australia, in the form of what Dr. Poore has called the dry catch system. In this system no dry earth is necessarily used, there is no pail, and the matter simply drops on a slightly sloping surface of slate, or other impervious material, from which the liquid rapidly drains off into the soil outside and into a receptacle filled with dry, absorbent material. The solid matter remaining on the surface, being thus separated from the liquid, rapidly dries and so is not only rendered inoffensive, but is greatly reduced in bulk and brought to a condition in which it can be removed by a shovel through a small door provided at the back, and so conveyed to the garden or other suitable place where it can be dug in. This of course can hardly be classed as an earth closet, although the drying process is to a certain extent the same.

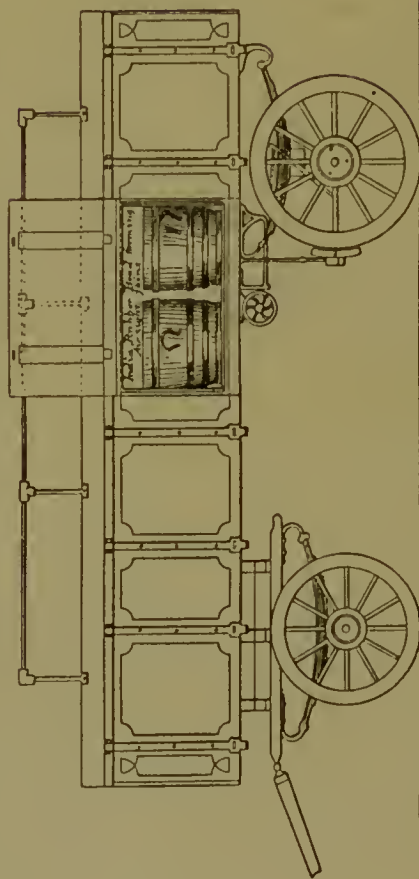
Dr. Poore, who is a strong opponent of the water-carriage system, has also recently introduced what appears to be a very successful method of dealing with urinals, wherein he has applied a modification of the method of absorption by suitable material, or, to speak with greater accuracy, an application of the bacteriological filter on a small scale. In this, a trough filled with suitable material is formed with perforated sides and bottom, whereby air is freely admitted to the body of the material in the trough.

The urine which is discharged on the upper surface material finds its way slowly through the mass, the time occupied being sufficient to enable the earth organisms to disintegrate, and change the organic matter of the urine, so that the liquid, which ultimately drops out at the perforations at the bottom of the trough, contains only inorganic matter, incapable of putrefactive change, and so rendered void of the possibility of offence. A urinal on this principle has recently been patented in Australia by Mr. Goodrich, of Moss Vale, which has been successfully adopted at a number of the suburban railway stations. In these cases the absorbent material used is fine sawdust, and in some of them the same material has remained for nearly a year without apparent change or offence. In these urinals no flushing water is needed, so they would appear to be eminently suitable where water supply is limited, or even unavailable.

The Pail System.—In the pail system the nightsoil is simply received into a movable receptacle, and collected without the addition of any foreign material. In the too commonly adopted application of this system, only one pail is provided for each house, and this is emptied during the night by the nightsoil contractors, at intervals which vary in different localities. The offensive appearance to the user of these pails has been already referred to, but the abominable nature of the emptying operations as practised in this single pail system, as it is called, has yet to be described. The nightsoil carts, as they are termed, are simply large covered boxes on wheels, more or less watertight, very often less. The nightsoil men who accompany these carts, are provided with two large buckets. Carrying these, they enter the backyards of the houses, and dragging out the full pail from under the seat of the closet, they pour, what they do not spill from the house pails, into their own buckets, replace the house pail, without any attempt at cleaning it, and carry the open buckets back to the cart and

NIGHT-SOIL CART AS USED WITH DUPLICATE PAIL SYSTEM.

Fig. 20.



again pour the contents with more or less accuracy into the cart. As in practically all cases neither cart, buckets, nor house pails are ever cleaned, their condition is horrible beyond description, and the nightsoil man and his appliances give ample olfactory evidence of his presence over the entire neighbourhood. This application of the system might be thought to have touched the lowest possible level of filthiness, but in cases where there are no regulations for the provision of even a decently-made single house pail, receptacles of the most leaky and objectionable nature are often used, and where—as is sometimes the case—there is no arrangement made for the regular emptying of the house pails, then the system (if it may be dignified by such a name) realises its most objectionable form. Such practices are the more reprehensible because there is really no necessity for them. Although the pail system cannot be entirely rid of its objectionable nature to the individual user, even this can be materially diminished, and the undoubted nuisance to the general public altogether done away with by the adoption of the double-pail system. According to this system a sufficient number of duplicate pails are provided to enable a clean house pail to be substituted for the filled pail—the latter being removed bodily to the cart and conveyed to the works, where it is emptied and cleaned. In this way there is no double pouring of the filth from one dirty receptacle to another, and as the pails are all made of one pattern and are provided with interchangeable air-tight covers, there need be no spilling and no smell caused by their removal or their conveyance in the cart through the district to the point of disposal. The cart can be kept perfectly clean, and the unobjectionable appearance of a properly constructed conveyance of this kind may be judged by the illustration (Fig. 20) showing the waggon used for this purpose at Rochdale in England. The process of emptying is as follows:—The cart leaves the works filled with emptied cleaned pails,

each having its air-tight cover. Arrived at its first place of call one of these pails is carried to the closet, the full pail is lifted out from its place, the cover of the empty pail is removed and fixed on the full one, the uncovered empty pail is placed in position and the full-covered pail is carried to the cart, where it replaces the empty pail removed. There is thus absolutely no offence possible during removal, so that the operation can be performed during the day.

There are a few municipalities in New South Wales, which, to their credit, have adopted this double-pail system, but the majority unfortunately have not.

Slop Water.—The common practice of discharging slop waters into the street gutters, particularly when, as is often the case, the water tables are unformed, is objectionable in the extreme. Slop waters become offensive in about the same time as nightsoil does, and when discharged into unformed gutters, they of course, collect in pools and rapidly give rise to nuisance. When a small area of garden is available, slop waters if distributed over it may be disposed of without the slightest offence and with considerable advantage to the growing plants. In the comparatively dry Australian climate a large quantity of liquid can thus be disposed of over a comparatively small area of ground, but it must be distributed *over* the ground and not merely allowed to dribble out or collect at one point of it. A carefully cultivated garden patch, of even 8ft. or 10ft. square, will be sufficient to dispose of the slop-water from a small household, with much advantage to the growing plants, if watered or otherwise distributed over the entire surface; whereas the same quantity of slop liquid, if constantly thrown out or discharged at one point, will not only destroy all vegetation but will cause the soil there to become sour, sodden, and evil-smelling. This is the underlying secret for the in-offensive disposal of slop water, and there are very

few places where a sufficient area of garden patch cannot be made available for the purpose.

Garbage.—In regard to ordinary garbage, its method of storage on the premises is what is most likely to come under the cognizance of the Sanitary Inspector, its removal and disposal being usually undertaken by the Local Authority. The old ashpit, or midden, wherein the household garbage was deposited, has already been described in this chapter; and the regulations regarding the storage of house-refuse, made by the British Local Government Board, and quoted in the last chapter, will give a good idea of modern practice in this respect. It will be sufficient here to add that in Britain the practise of providing small movable galvanized iron dustbins, having hinged weather-proof covers, is being more and more generally adopted. The great point in regard to the household storage of garbage is to prevent the access of moisture, and to provide means for the escape of moisture existing in the garbage, so that it may dry up as far as possible, and so be preserved from offensive decay. To this end wire receptacles of close mesh, which allow a free circulation of air, are sometimes used and found serviceable. Boxes, constructed of absorbent and decaying material, such as wood, are highly objectionable for this purpose.

As to the removal and disposal of garbage, all that need be said here is that the removal should always be done in closely covered carts, so as to prevent the wetting of the garbage by rain, or the loose material and dust being blown about by the wind. As to the disposal of the garbage, the commonly adopted tip system is extremely dangerous, particularly when the garbage is used for making up building sites—masses of garbage so disposed of inevitably result in offensive decay, and lead to the pollution of the air and of the subsoil water. When disposed of by burial, what is called the cut and cover system is the best. In this method the garbage is to some extent mixed with the soil, being buried in comparatively shallow trenches

lightly covered with soil. When this is done in suitable soil, the garbage quickly and inoffensively disappears, and after a comparatively short time the same area can again be trenched and used for the burial of fresh garbage without causing nuisance. Disposal by burning is undoubtedly effective, and in some cases is actually the cheapest method—but the burning must be done in properly constructed destructors, as they are called. Any attempt to burn garbage in open heaps will inevitably result in serious nuisance, and for that reason should never be adopted.

Properly constructed garbage destructors are simply efficient smoke preventing furnaces, so designed as to deal with a very dirty and inferior fuel. The observations made in chapter 8, as regards the proper construction of furnaces, apply equally to garbage destructors, and the principles there set forth will furnish a general idea of the points required in a satisfactory garbage destructor.

The Water Method.—The water method of sewage removal is simply carrying out what we have already stated in another place, viz., that all waste matters should be removed as soon as, as effectively as, and as cheaply as, possible from all buildings. It is impossible to conceive any cheaper and readier method of sewage removal than the water carriage system. Closely engrafted on this system, in fact, forming the most important part of it, is the water closet. The conveyance of faecal matter from latrines is a practice of considerable antiquity, and we read that some latrines, in the time of Augustus, discharged their contents into sewers, and had an ample water service by which their contents were flushed into the sewers. Fosbrooke relates that there existed in the palace of the Cæsars, a water closet furnished with a cistern, from which water was distributed to several seats, and there is still to be seen a specimen of a water closet removed from the ruins of Pompeii.

It is supposed that Rome gained the knowledge of this sanitary convenience from the East. When Rome fell, civilization was put back centuries, and sanitation was forgotten. Still the Cloaca Maxima, the monument to the old water carriage system, stands, and there is every evidence that Rome was advanced in matters of sanitation, although there is no doubt but that the Sanitary Inspector travelling round with his smoke test would have caused trouble and given grievous offence. The history of the Canterbury Cathedral reveals that many years ago there existed within it privies, or fourth dormitories, opening into a fosse which was flushed with rain water falling from the roof of the building, and Aubrey, in his "Surrey," mentions a "pretty machine for cleansing away filth from a privy." Notwithstanding all these movements in the right direction, it was not so many years ago that each house had its hole in the ground for storing faecal filth, and cities were cursed through this midden system. In 1778 Joseph Bramah re-invented the water-closet, and it gradually crept into use till the year 1813 when it was further perfected, and came into general use 1828-33. The principle of the water-closet was a good one, and although, perhaps, at first its method of working was, through want of experience, not only imperfect, but even a source of danger, still defective as it was, and often still is, it was superior from a sanitary point of view to the privy. Through the water-closet system of drainage, the direct pollution of the soil by excreta has been considerably lessened, and succeeding years have brought about those improvements which have made the water-closet not only a convenience but also a safeguard of health. However pure the air surrounding the house may be, however dry the site, and however wholesome the water, that house cannot be healthy unless a system is provided to convey from its precincts all the liquid refuse before decomposition has set up. The advent, or rather the reappearance, of the water-closet caused

a reaction against the midden system which it gradually supplanted, and it brought about a great improvement in sewerage systems, which before its advent were in a very primitive state. The gradual improvement of the water closet is an example that progress is not effected by indifference and want of appreciation, but that Science, "if it is really to do for a people all that it is its duty to do, must be a living thing, a vital principle in the hands of men, and must not be represented by a dead routine."

On account of the method in which modern sanitary fittings, with their necessary waste pipes, have grown up within our dwellings, and the gradual adoption of water carriage for the removal of household wastes and nightsoil, and the replacement of the old cesspit by the modern sewerage system, the most extraordinary arrangements and mingling of modern and obsolete sanitary works are constantly being discovered in our older towns. It would be impossible in the space at disposal to attempt even to indicate the absurd and dangerous nature of many of those defective arrangements. We will, therefore, rather endeavour to describe the general principles upon which the best modern work is based in regard to house drainage, waste and soil pipe design and sanitary fittings.

Drains — In all modern work the house drains are constructed of what is called salt-glazed earthenware pipes. These are made with sockets at one end, into which the adjoining pipe fits, and should always be jointed in Portland cement, and in such a manner that the invert of the pipe, as it is called, that is the bottom part of the inside, shall be laid in a perfectly straight uninterrupted line, that is to say, the joinings of the adjacent pipes must be perfectly level, the one pipe not dropping below nor rising above the other, and there being no pieces of the cement jointing left projecting inside, which is a fruitful cause of stoppages in drains. The house drains must always be cut off from the sewer by a water seal trap, which is called the

main disconnector or boundary trap. This trap forms the first line of defence against the sewer gases. The drains should be laid in straight lines, and all joinings of branch drains ought to be by what are called sloped junctions—special pipes are made for this purpose, and the meaning of the term is, that the branch pipes must join the main drain in the direction of the sewage flow, and never at right angles to it.

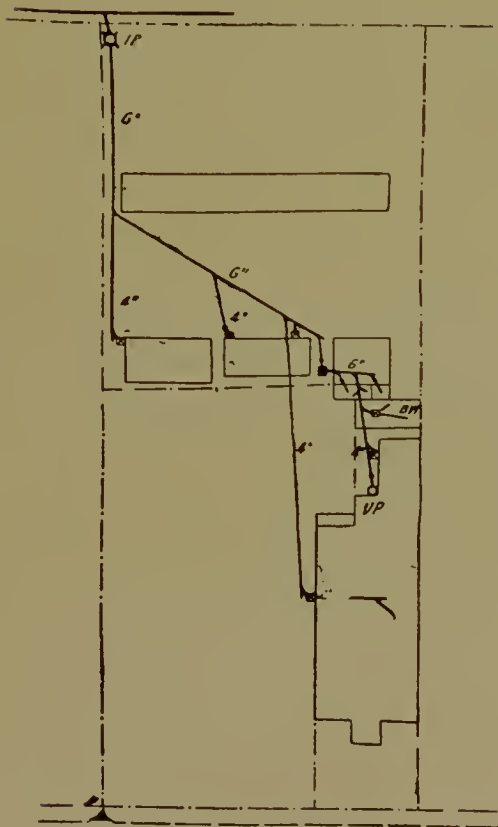
Drains should never be carried under a house where it can be avoided, but where this is absolutely necessary, they should pass in a straight line from side to side, and in such cases the earthenware pipes should be surrounded by concrete, as an additional security against leakage or settlement. Branches should never enter a main drain under a building, because stoppages often take place at such branches, and when in such a position they are almost inaccessible. All modern drains are jointed in Portland cement, instead of clay, as was formerly the case. Clay-jointed pipes rapidly choke up, by the growth through them into the pipes, of tree roots, which often completely fill up the bore of the pipe in a tangled mass. Tree roots will stretch long distances underground in search of moisture, and instances have been found where the roots of comparatively small trees had extended for between thirty and forty feet towards a drain, and, growing through between the joints, had completely stopped the pipe. Clay joints also form a ready access for rats, as there is room in the jointing space between the socket and spigot end, as it is called, of the adjoining pipe, for their passage. Clay joints, also, do not confer any stiffness to the junction between the pipes as cement does, so that a very slight force is sufficient to bend or draw asunder clay-jointed pipes, so destroying their grading and causing the joints to break.

Tree roots and rats cannot force their way through cement joints, hence their universal use in modern work. In the very best work, what is called Hassall's patent joint is often used. This is a combined

joining, comprising a self-fitting joint, stiffened and secured by a cement joint. It has the advantage of securing perfect grading at the joinings, and of making sure that none of the cementing material can run into the pipe, and form an obstruction to the flow. It is, however, more costly than the ordinary joints, and is not, as yet, manufactured in these colonies. The very strength of cement jointings, which form their security, renders it impossible to obtain access to stopped-up drains, without actually breaking up the pipe. For this reason special access pipes should be provided near all points where stoppages are likely to occur, such as at branches and traps, and these are also desirable at about 40 feet intervals on long stretches, even of straight pipe. These consist of an oblong opening (about two thirds the length of a section of pipe) formed on the top of the pipe, and having a loose cover resting in a socket. This is secured in its place by a poor cement, sufficiently strong to resist rats, but which can be picked out without fracturing the pipe, so as to enable the cover to be removed, when access for clearing any stoppages is required. These openings are made oblong so as to enable drain-cleaning rods to be easily introduced into them, and they should be placed so that the entire length of the drain can be reached easily by these rods. At points where it is necessary only to introduce the hand, such as immediately behind the traps of yard gullies, and at the foot of soil pipes, ventilating pipes, and the like, a sufficient form of access opening may be obtained, by using what is called a square junction, turned vertically and closed with a movable earthenware disk jointed as already described. A square junction is a length of pipe having a branch socket set at right angles, instead of sloped with the flow, as in the sloped junction. These square junctions should be used only for such access openings, or for the joining of ventilating pipes to vertical or horizontal drains, or for branches delivering into vertical pipes, as at

DRAINAGE PLAN AS ISSUED BY THE SYDNEY BOARD
OF WATER SUPPLY AND SEWERAGE.

FIG. 4.



DESCRIPTION.—I.P., main disconnector trap and inlet, placed just inside boundary fence and close to the main sewer; B.W., bath waste pipe; V.P., vent pipe. The small squares indicate disconnector gullies or sinks, taking discharges of the waste pipe class. The larger black square indicates a junction pit for access, where one or more drains join at various angles; these junction pits have cemented bottoms, with channels formed in easy curves continuing the pipes leading into them to the pipe forming an outlet from them. They are usually built in brick, cemented on the inside, and covered in with a stone or

iron cover, forming an access for inspection or repair.

the continuation upwards, to the surface, of the disconnector trap, or where a deep sewer has to be connected with a house-drain, much nearer the surface. They should never be used for any ordinary horizontal junction, and indeed are absolutely prohibited in such places by most authorities.

Traps.—Drain traps, and fittings traps, consist of bent pipes, the bend being turned downwards. In this way sufficient of the flowing liquid is always retained in the bend to block the pipe, so far as access of air is concerned; and it has been proved by Dr. Carmichael, of Glasgow, that this water seal, as it is called, forms an absolute barrier against the passage through, it of the living organisms which form the dangerous constituents of impure drain air, and which produce rapid putrefactive change when allowed access to meat, fish, etc. The same authority also proves that only the most minute quantity of the inorganic gases, found in even the most badly-ventilated drains, could pass through a water-seal; quantities so small as to be imperceptible to the senses, and perfectly harmless to health. This protection, however, only exists so long as the drain gases are not actually blown through, or caused to bubble through such a water-seal. This might, and did happen in fittings when the necessity for guarding against it was unknown, and was due to the action of flowing water, or of tides, which under certain conditions could induce a pressure, or create a suction in unvented pipes, far more than sufficient to blow out or suck out the water lying in the bent pipe. The latter action is known as the syphonage of traps, and one of the most important functions of the modern system of providing free ventilation throughout the entire drains and house waste pipes, is, so as to render this blowing-out, or syphonage an impossibility. All water sealed traps may be classified under two broad divisions—disconnectors and interceptors. Both of these divisions have a water seal as an essential portion, but the disconnectors have in addition a disconnecting opening to the outer air pro-

vided on the *house side* of the water seal. This opening forms the disconnecter portion of the trap, which is intended to prevent any gases, which may pass through the water of the seal, or by any chance be forced through it, from being conducted in a closed pipe to the interior of the house. The mere interceptor traps do not possess this safeguard, the pipe on the *house side* of the water seal being in them continuous to its opening into the fitting. Disconnecter traps are used for the main interceptor, or boundary trap, for all yard gullies or drain sinks, and for what are called grease traps, which are fixed in large establishments so as to receive and congeal the hot grease from the scullery sinks, and prevent it from hardening on the sides of the drain pipes beyond, and so choking them up. Interceptor traps are mostly used in connection with the interior sanitary fittings, and one of these should be fixed as close as possible under each individual w.c., urinal, basin, bath or sink. Drain traps may be further subdivided into two classes—the self-cleansing, and the non-self-cleansing or arresting traps. The former are constructed in the shape of a bent smooth pipe throughout, so that the rush of water washes all solid matter clean out of them, and so forward to the sewer. The latter form are purposely made of a square, or box shape, towards the house side of the bent pipe; this is done so that matters, which from their weight, or other reasons, would be likely to choke the drain, such for instance as grit, or gravel, from unpaved yards, or road surfaces, will be deposited or arrested in this box, from which they can readily be cleaned out at intervals, hence the name, arresting traps, given to this class of fittings. The main disconnecter trap, all disconnecter gullies receiving the waste pipes from what are called the waste pipe class of fittings, and all the interior intercepting traps, should be of the bent pipe or self-cleansing class; yard, or road gullies, and also grease traps, should be of the arresting class; but in regard to the latter fitting, the arresting action

should, if possible, extend only to the floating grease, and the trap should be so formed that all sludge passing into it should be washed through as in the self-cleansing form. It may be mentioned here that a large number of the defects found in old sanitary fittings and drains, arose from the fact that their parts, traps and pipes, were not of a self-cleansing form, so that deposits of sludge and filthy splashings, in positions that could not be reached by the flushing water, accumulated for years, at numerous points where access for cleansing was impossible. Of this type were the old fashioned receiver or pan closets, the lead D traps, often fixed under them, the objectionable cast iron bell traps, lip, or D traps, and pot traps; none of which could be directly connected to the drains (as all modern drain gullies should), which were not in themselves self-cleansing, and which had, of necessity, to be fixed over brick pits, which from their shape and construction were often merely leaky cesspits, accumulating filthy and decaying sludge. Even the main "cut-off" trap, corresponding to the modern boundary trap, where such a protection (?) was provided (which was seldom), consisted of a square brick pit, having a tongue or dip-piece, as it was called, formed of a piece of slate or paving built across it, with its lower edge dipping below the surface of the liquid. These traps were seldom, if ever, air-tight, were most certainly not self-cleansing, and, in fact, simply formed cesspits, and very often leaky ones at that, from the surface of which the festering gases of putrefaction found their way into the house drains, and too often through defective fittings into the houses.

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House Fittings.—Coming now to the waste pipes and sanitary fittings within the house, the best British and Australian practice calls for the separation of these fittings into two groups, which must be kept entirely distinct and disconnected from each other. These may be conveniently described as the

“soil pipe” group, and the “waste pipe” group. The former includes all water-closets, urinals and house maids’, or bedroom slop sinks, with their waste pipes, etc., and under the latter class are included all the other sanitary house fittings, such as baths, basins, washing up and scullery sinks, and washtubs. It may be added that rain water pipes or down spouts are also considered so far as their delivery into the drains is concerned, as being of the second class, but they must not be joined to any waste pipe of either class, but be carried down independently to their point of discharge. According to N.S.W. and Victorian regulations, all wastes of the soil pipe class are connected directly to the house drains, that is to say, that their only protection from the sewer gases, exclusive, of course, of the interceptor traps under each fitting, is the main disconnector or boundary trap. All wastes of the waste pipe class are required to be disconnected in addition, from the house drains, by being discharged over a drain gully, or sink trap, which should be of the self-cleansing type. In addition to the protection afforded by the intercepting traps under each fitting, the waste pipe class is thus doubly disconnected from the sewer by the main boundary trap, and from the house drains and soil pipe class, by the drain gully, or sink, over the water seal of which it discharges. It will thus be seen that the soil pipe class which is likely to contain the more dangerous matters among the household wastes, is thus as effectually cut off from the whole of the waste-pipe class of fittings, as are the house-drains from the sewer. The venting and ventilation of the traps, wastes, and drains, already referred to as necessary, to prevent dangerous pressure or suction acting on the water seal, and which is also required to prevent the accumulation and dangerous concentration within the pipes, of the gases and vapours arising from organic matters, which may adhere to the sides of the pipe, is effected as follows. Ventilation through the house drains is effected by

two openings to the outer air, placed as near as is possible at the opposite ends of the house drains, and in the best work, at the upper ends of all long branches joining the main house drain. In addition to these openings, all wastes of the soil pipe class must be carried up full size through, and well above the roof. These, therefore, also form additional ventilation openings for the main house drain, and the soil pipes from closets, which are usually of 4 inches diameter, may be accepted as serving as one of the two openings just mentioned, where they are situated sufficiently near either end of the drain to enable the proper ventilation of the greatest length of the drain. Each pipe of the waste pipe class, is arranged to be open at both ends, so as to ensure a through current; the lower end, of course, being open to the air, where it discharges over the water seal of the drain gully, and the upper end also being carried up full size above the roof and left open. In addition to these arrangements, what are called back-vents, should be provided. These pass from the highest point, of the bent-pipe, forming the interceptor traps, under each fitting, on the side of the seal farthest from the house. These vents may be joined together, taking care not to unite vents from the two groups, and may be carried up in one common vent, which may either be continued through the roof to the open air, or carried into the soil pipe, or the waste pipe, as the case may be, at a point above the level of the highest branch, discharging liquid matter into it. These back vents are particularly necessary for the safety of the interceptor traps, when these are on branch pipes of some length, but they are also a necessity even when the traps are quite close to the main, waste, or soil pipes, if there is another fitting discharging into it at a higher level. In the case of isolated bath or basin fittings, this back vent may be carried through an outer wall, and left open to the air, at a point close to the fitting, provided there are no windows near it, where any slight odour

finding its way through the back vent might enter. It is desirable, wherever possible, to carry the ventilation openings at each end of the drain, well above the ground level, and removed well from the neighbourhood of any window opening. This is so because, particularly in still weather, there is no certainty in which direction the ventilating current may pass. The popular idea that drain or sewer air will always ascend to the highest point, and find exit there, is totally erroneous, and these currents may just as often be found descending to the lowest point, and finding their exit there. Many causes influence the direction which the air may take. For instance, the earth temperatures already referred to have, during summer, the effect of cooling underground drains to a temperature considerably lower than the outer. This causes the air in the drains to become heavier than that on the surface. Therefore it would be put in motion towards the lowest point; that is, it flows down the drain just as the water does, and so induces a current inwards at the highest opening at the head of the drain, and outwards at the lower end. In winter time, the earth temperatures being higher than those on the surface, the drain air is warmed, and so tends to ascend, thus passing in at the lowest opening and out at the highest. Even under those conditions, however, the current may be instantly reversed by the discharge of a flush of water into the drain. This acts partly, by suddenly, but temporarily, cooling the air in the drain, so causing it to descend instead of to ascend, and this motion is hastened by the friction of the water flowing downwards dragging the air with it. Similarly in summer time the downward current, due to the earth temperatures, may be instantly reversed, by the discharge of a quantity of hot water from the kitchen or wash-up sink passing through, and so temporarily heating the drains. Again, the heat of the sun, by warming the upright portion of the metal ventilating shaft exposed to its

DESCRIPTION.—The vent pipe at lower end of drain and the continuation of soil pipe are carried up to form ornamental finials. The waste pipes from basins and baths and also the weeping drains discharge over a self-cleansing disconnecter trap in yard between buildings. The gully shewn in back yard is of the disconnecter-arresting type, and a mica flap inlet drain ventilator is shown beside it. It will be noticed that the pipe ventilators and pipe vents of the back vents of the soil pipe and of the waste pipe groups are kept strictly apart.

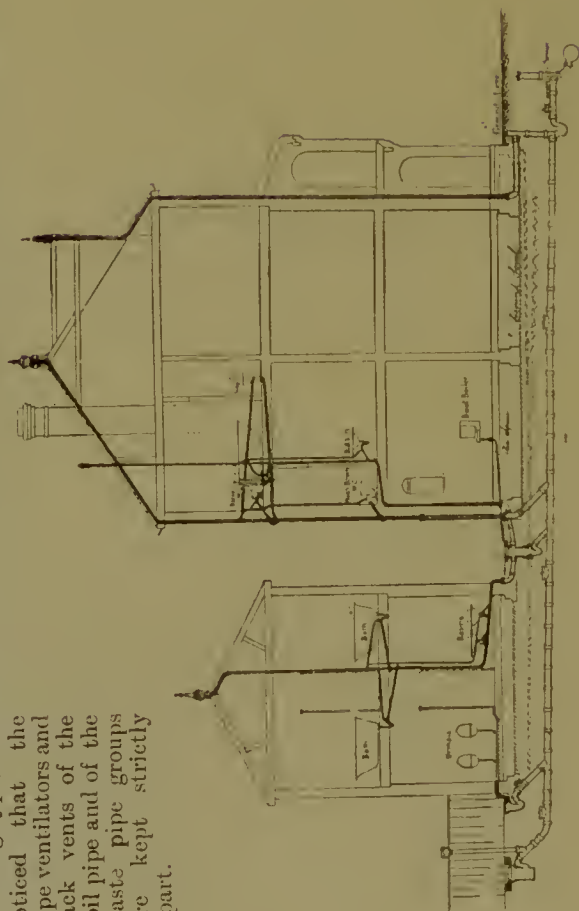


FIG. 21.
MODERN ARRANGEMENT OF HOUSE DRAINAGE AND INTERNAL
SANITARY FITTINGS.

Examination diagram, Department of Sanitation, Sydney Technical College.

rays, may overcome the earth temperature, and cause a current upward through that shaft, and this may induce a current in the drains, either upwards or downwards, according to which ventilation shaft is exposed to this influence. It is true that when there is any wind, the direction which the current will take may be ensured with fair certainty by fixing an educt cowl on one shaft, and an induct cowl on the other ; but the wind is not always blowing, and in still air these cowls are useless, so that under these circumstances, the influences above mentioned determine the direction of the currents. It is therefore desirable, as already stated, that both shafts should be carried sufficiently high to enable the current to pass in one direction or the other, without causing nuisance. When this cannot be done, as where the appearance of a ventilating shaft passing up the front of a building is objected to, or where constructional difficulties interfere, it is usual to carry the shaft at least 3 or 4 feet above the level of the ground and terminate it with what is called a mica flap inlet ventilator. This is an arrangement whereby thin mica sheets, hanging against a grating, close against any outward current, so being supposed to prevent any outlet of drain air, but open easily in response to the slightest inward current. In such cases an educt cowl should of course be fitted on the bent shaft at the opposite end of the drain. The diagram (Fig 21) which is reproduced from one of the Sydney Technical College plumbing exam. drawings, will give a general idea of the arrangements described, and shows in addition how ventilating shafts or pipes can be carried up so as to form an ornamental feature of the building. This diagram also shows a suitable method of connecting the subsoil drains, or weeping drains, as they are called, to the house drains, so as to prevent the possibility of drain air finding its way through the weeping drains, and so into the house by way of the soil under it. In the case of weeping drains, and also of down spouts

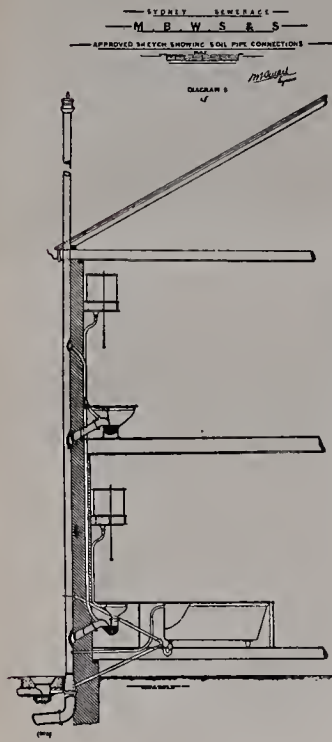
for rain water, where during dry periods long intervals may elapse during which there is no flow of water through those pipes, ordinary water sealed traps are useless, because of the almost inevitable drying up of the protecting water seal due to its non-replenishment during such periods. It is therefore necessary to discharge such pipes over the water seal of some disconnecting drain gully trap, which is kept constantly replenished by the discharge from some frequently-used fitting of the waste pipe class, and this, it will be observed, is what has been done in the diagram given. The diagrams (Fig. 22 and 23) which are reproductions of those issued for guidance by the Sydney Board of Water Supply and Sewerage, show the details of the soil, the waste pipes, and also of the back vents more clearly. It should, however, be noted that the disconnecter drain gully shown in connection with the waste pipe class of fitting in Fig. 23, is not of the best form, and is now abandoned in Sydney in favour of a self-cleansing gully, consisting of a simple bent pipe, having its opening to the air on the house side of the seal, enlarged to a hopper form, and covered with a grating so as to form a gully or drain sink.

Internal Sanitary Fittings.—The diagrams, Figs. 21, 22 and 23, show the sectional forms and connections of a number of the most commonly used house sanitary fittings. In all of these in modern work two main points are aimed at. 1st. That they should be self-cleansing in every part. 2nd. That all mechanical or moving parts should be done away with as far as possible. Having then these requirements in view, we can now proceed to consider a few forms of these appliances which may be taken as types of the multitudes of such fittings now available.

Water Closets.—Perhaps the most important house-fitting from a sanitary point of view is the water closet. The type of those appliances now accepted as more or less satisfactory, from a sanitary standpoint, may be conveniently classified under four general

SECTION SHOWING APPROVED FLUSH, WASTES, BACK VENTS, VENTILATOR, AND FITTINGS FOR WASH-DOWN CLOSET, SLOP-SINK, AND BATH.

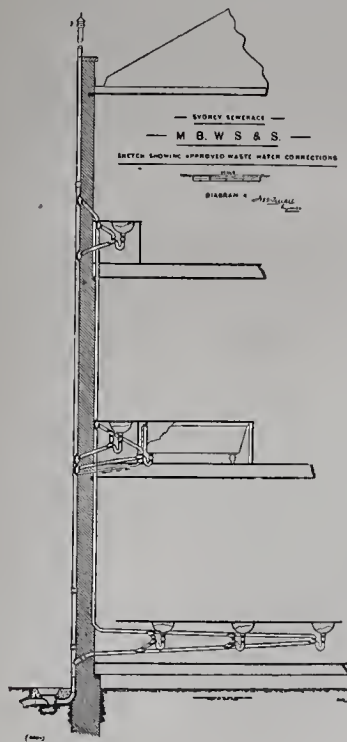
FIG. 22.



DESCRIPTION. — In this drawing, the disconnector yard-sink, or gully, shown taking the waste from the bath is of a type now condemned by the Sydney Board of W. S. and S., being non-self cleansing.

SECTION SHOWING APPROVED WASTES, BACK-VENTS, VENTILATOR, AND FITTINGS FOR BATH AND WASH-HAND BASINS (Single and in Range

FIG. 23.



DESCRIPTION. — In this drawing, the disconnector yard-sink, or gully, shown taking the waste from these fittings, is of a type now condemned by the Sydney Board of W. S. and S., being non-self cleansing. (See letterpress, page 284.)

heads. 1st. The valve-closet class (the modern development of the Bramah closet). 2nd. The wash-out class. 3rd. The wash-down class. 4th. The syphonic class. Of these the valve-closet class comprises the only mechanical form of closet now deemed satisfactory, the other three types having no moving parts. The point of a good closet of any of the four types may be shortly stated as follows: There should be no corners not reached and thoroughly washed by the discharge of the water flush; in other words, it should be thoroughly self-cleansing. It should be so constructed that the soil will be certainly, and entirely, passed into the soil-pipe by the action of a single flush. The water remaining in the closet after use, and flush, should have sufficient surface area, and be of sufficient depth, to prevent the possibility of the fouling of the earthenware pan or basin by the falling soil during usage, and there should be no possibility of this water draining off and leaving the basin (or bowl, as it is called in the United States) dry. It should be constructed of impervious and smooth highly-glazed material, such as glazed china or stoneware. The flushing water should be directed downwards over the sides of the basin by means of a flushing rim, as it is called, and never around the sides, as in the lead pans of the obsolete pan or earthen closet, or taking a gyratory motion as in the now repudiated long hopper-closet. It should be perfectly noiseless in its action, and the flushing water should be discharged so quickly as to fill and so thoroughly flush the trap underneath and the soil-pipe beyond the closet. No individual apparatus in any of the classes named fulfils entirely all those requirements; but each has its own advantages, and it may be added, disadvantages.

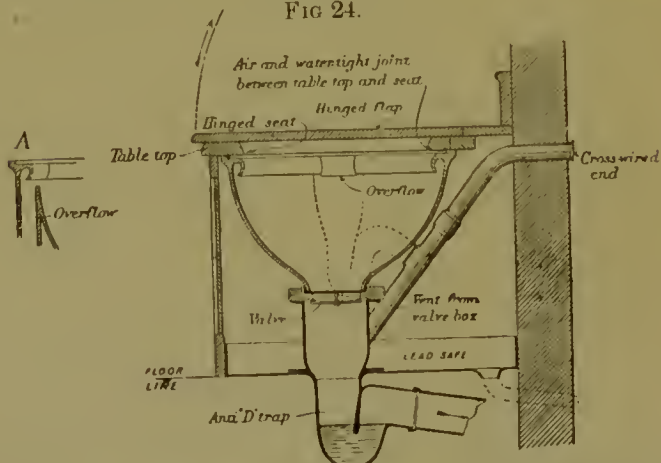
Valve Closets.—Perhaps the greatest advantage of the valve closet is its noiselessness in action. This enables it to be placed in the neighbourhood of dwelling rooms without offence, where it would be impossible to locate a closet of any of the other

classes, because of the noise made by the flushing discharge. The extent of surface and depth of, the water contained in, together with the shape of the pan, in the valve closet, fulfil perfectly the non-fouling conditions required. The flushing arrangements are also good. There is a flushing rim, and the sudden opening of the valve at the bottom of the pan drops the large quantity of contained water in a mass through the lower part of the closet, and the pipes beyond, thus causing a sufficient flush in every corner and discharging the entire contents with certainty. This type of closet requires, what is called, an after flush cistern, that is, a second flush, which again fills up the pan after the dropping of the handle and the closing of the valve. The discharge and flush of these closets is usually actuated by the lifting up of a handle in the seat. There are two other types of closet which are actuated in the same way, and with which the Inspector must not confuse the valve closet. These are the pan, or container closet, a most objectionable type, which should be condemned wherever met with ; and the plug closet, which is very good in some respects, but not sufficiently self-cleansing in all parts to be quite satisfactory.

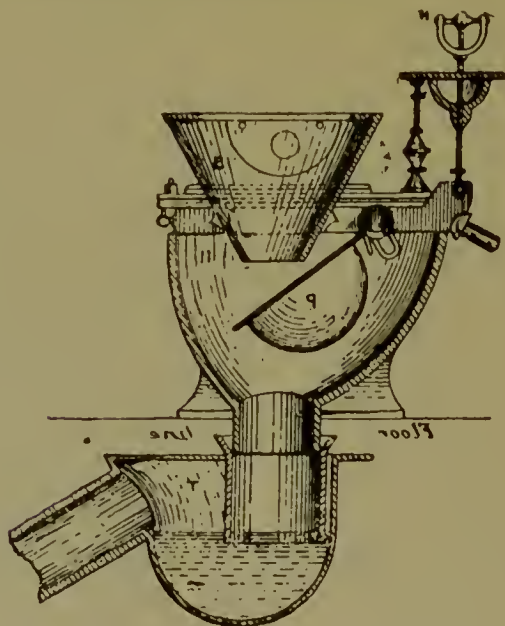
The points which may be considered defective in the valve closet are : 1st, its having mechanical parts ; 2nd, that it is enclosed in wood-work in order to cover up the unsightliness of its working parts ; 3rd, that if the valve does not close water-tight, the pan drains dry and is then necessarily fouled in usage ; 4th, the interior of the intercepting trap under it, is out of sight of the user. In regard to these defects in good class closets of this type, the first noted point is not serious, because their mechanism is so simple, that when well made, they are found to work satisfactorily for very many years. The second defect is more serious ; any enclosed space around a closet is looked upon as undesirable, because it is commonly never cleaned out, and so may become a harbor for dirt and vermin, and further, any enclosure around a w.c.

SECTIONS OF VALVE AND PAN CLOSETS TO SHOW CONTRAST.

FIG 24.



IMPROVED COMBINATION VALVE CLOSET, WITH FLUSHING RIM AND RIM OVERFLOW BY HELLIER—GOOD FORM.



PAN CLOSET AND D TRAP.—BAD FORM.

B, glazed earthenware bowl with lead fan flush ; Q, copper pan, working in cast iron receiver ; T, D trap ; H, actuating handle.

apparatus is certain to be more or less damp, and so induces the decay of the enclosing wood work, and of any organic matter which may find lodgment in it. The third defect mentioned is also a real one, because the accidental lodgment on the valve, of anything that may prevent it closing properly against its seat, such as paper, or the like, will of course cause all the water to drain away, and so destroy its non-fouling qualification. It should, however, be added that, on account of the quick and copious flush, such an accident very rarely occurs. For the same reason the fourth defect is not of great importance. The object of having the interceptor trap visible to the user is to enable him to *see* that it is thoroughly cleaned out with the flush. This point is fully attained in all closets of the wash-down or syphonic type, and to a lesser extent in the wash-out type.

On the whole the valve closet is accepted as a satisfactory sanitary fitting, and the illustration (Fig. 24) gives a section of a high-class closet of this type by Hellyer, which will enable the various parts to be readily understood. The hinged seat shown, is an arrangement now almost universally adopted for all types of closet, and is termed the "Combination," valve, washout, or washdown closet as the case may be. Its object is to permit of the seat being lifted up and thrown back, so that the closet can be used as a urinal or slop sink, without risk of fouling the seat.

Washout Closets.—The washout is a non-mechanical closet usually made in one piece (including pan and trap of highly-glazed china or stoneware). In this closet the soil is received in a shallow saucer-shaped pan, having an overflow usually at the front part, to a trap, the level of this overflow being such that a shallow lake of water is always retained in the bottom of the pan. The flush is by means of a flushing rim, which is so constructed that in addition to the downward flush round the sides of the pan, there is also a jet of water

directed forward and downwards towards the centre of the saucer-shaped part, which washes the deposited matter over the edge of the overflow into the trap, and is supposed also to carry it through the trap into the soil pipe. This is on the whole a good closet; it has no mechanical parts, does not require any wood enclosure, is of neat appearance, as may be seen from the illustration (Fig. 25), and being constructed of impervious and highly-glazed material throughout, it is readily cleaned. It has, however, two rather serious defects: 1st, the contained water, although of good surface area, is too shallow, effectually to prevent fouling of the bottom of the pan or basin; 2nd, the flush, though thoroughly effective in clearing out the contents of the basin, so loses its force against the upright sides of the trap that it cannot always be depended on to wash the whole of the floating matter through the trap into the soil pipe in *one flush*. In the best forms of this type an attempt is made to obviate this rather serious defect, by curving the upper part of the trap towards the overflow from the basin, so as to direct the flush as far as possible downwards on to the surface of the water seal.

This is a decided improvement, although it cannot be said to have effected a certain cure in all cases. In this respect the washdown type is much superior to the washout, because in it, the flush discharges directly on to the surface of the water seal of the trap, which in this case also forms the water surface in the closet-pan. The diagram (Fig. 26) shows sections through a washout and a washdown closet, side by side, and at once indicates the construction of both types, and enables a comparison to be made between the two.

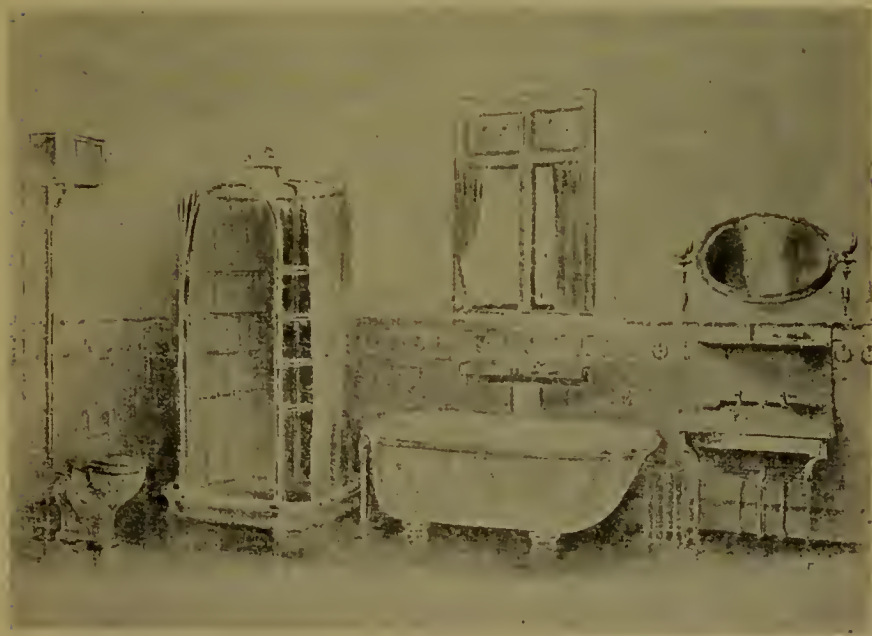
Washdown Closet.—The washdown is also a non-mechanical closet usually constructed entirely of glazed china or stoneware, although in some cases a portion of the trap part is made of metal. This type may be said to be the acme of simplicity in closets. As already stated, it consists simply of a disconnecter

THE SANITARY INSPECTOR'S TEXT BOOK.

MODERN BATHROOM AND WATER-CLOSET.

Showing unenclosed sanitary appliances, comprising syphonic closet, independent shower douche and spray apparatus, plunge bath, and wash-hand basin, fitted with hot and cold water supply.

FIG. 2 .



SECTIONS OF WASH-OUT AND WASH-DOWN CLOSETS
SHEWING CONTRASTS.

FIG. 26.



Section of Wash-down
closet.



Section of Wash-out
closet.

trap, having the water seal on the house side enlarged, so as to form the closet-pan. It is provided with a flushing rim, which should be made so as not only to wash the sides of the pan all round, but also to provide a strong plunging flush, directed downwards over the surface of the water seal, in order effectually to drive all floating matter through the trap in a single flush. This is the greatest difficulty to be overcome in this type of closet. When improperly made, the flush simply churns floating matter about, without driving it through the trap, and of course the larger the surface of the water seal in the pan, the greater the difficulty in overcoming this defect. This has led to the construction of apparatus of this type, with a water seal surface, so restricted in area, in order to secure thorough flushing out, that it is far too small to enable fouling of the pan to be avoided. In order to prevent this fouling, so far as possible, it has become the practice to make the back of the pan vertical, or in some cases sloping backwards towards the bottom. But even this without a sufficient area of water surface is only partially successful. It may, therefore, be laid down that the best form of this type of closet, is that which, having a sufficient area of water seal surface to avoid fouling of the pan, has its flush so arranged as to wash out all floating matter with certainty, by the action of one flushing discharge. These points being attained, it may be taken that, in the wash down type of closet, we have the simplest and most sanitary appliance at present available. Among its numerous good points, the wash-down closet includes that of the non-necessity for any enclosing wood work, and in the better class of this type of apparatus now in the market, there are to be found examples, which, in point of design and decorative treatment, are of very high artistic merit.

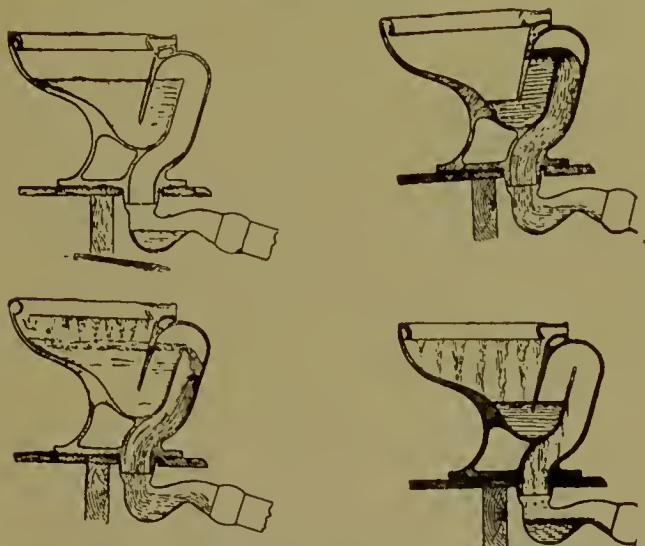
The Syphonic Closet.—The difficulty already referred to of securing in the washdown closet a sufficiently large area of water seal surface with an

efficient cleansing flush, has led to the invention of what is known as the syphonic closet. This is really a modification of the washdown closet, wherein the driving action of the flush is assisted by the sucking-out action of a syphon, which in this type is formed simply by what is in effect the elongating of the intercepting trap. By this means the trap is made to serve a double purpose, namely, that of a protecting water seal, as in the washdown closets, and in addition that of a syphon which, by its suction, absolutely ensures the withdrawal into the soil pipe of the entire contents of the pan, no matter what the size of the water seal surface is. The advantages of this are obvious, and its only disadvantage lies in the somewhat more complicated arrangements needed in the first place to start the syphon action, and in the second place to provide an after flush which shall with certainty again fill up the pan after it has been emptied by the syphon. Were it not that this to some extent does away with the extreme simplicity of the washdown, the syphonic would be its superior. As it is, if not its equal, it may be taken as being the second best type in the market. The Figures 27 and 28 illustrate two forms of this type. In Fig. 27, which is known as the "Deceo" closet, the syphonic action is started by the ordinary pan flush, and the illustration shows four periods of its operation. In Fig. 28 the syphonic action is started and assisted by the jet flush shown at the bottom of the pan, and directed upwards along the ascending portion of the combined syphon and water seal.

Slop-Water Closet.—In addition to these typical forms of house water-closet, another may be mentioned, which has proved of much service where the available water supply is limited in quantity. This is known as the slop-water closet. The diagram (Fig. 29) illustrates the arrangement of a good form of this apparatus. It will be seen that this closet consists essentially of a sort of drain gully, the flush being obtained by collecting

SYPHONIC CLOSET ACTUATED BY ORDINARY FLUSH.

FIG. 27.

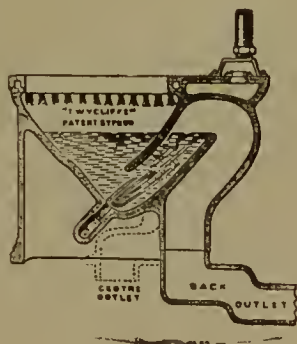


DESCRIPTION.—The drawings shew four phases of the operation. 1st, the closet filled up by the after-flush and standing ready for use; 2nd, the beginning of the flush, shewing the formation of the syphon action; 3rd, the main flush expended and the pan emptied, the period being the instant before the syphon action is broken by the passage of air into the pipe at the bottom of the pan or bowl; 4th, the syphon broken, a portion of the water having fallen back into the pan, and the after-flush again filling up the pan to the level shewn in first period, in which condition it remains until the next usage and flush.

SYPHONIC CLOSET ACTUATED AND ASSISTED BY JET FLUSH.

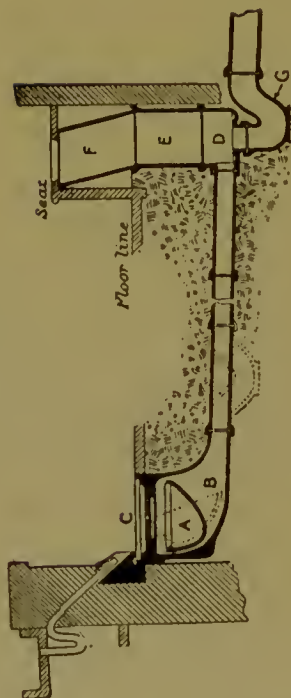
FIG. 28.

DESCRIPTION.—In this type the Syphon action is started, and the complete emptying of the bowl or pan ensured, by the inductive force of the jet flush shewn at the bottom of the water seal. The construction causes the main flush to divide into two, one part forming the rim flush, and one the jet flush. In this closet an after flush is also required again to fill the pan, when the jet flush is exhausted.

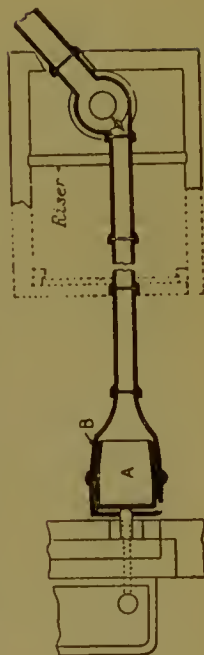


SECTION AND PLAN OF SLOP WATER CLOSET.
(DUCKETT'S PATENT.)

FIG. 29.

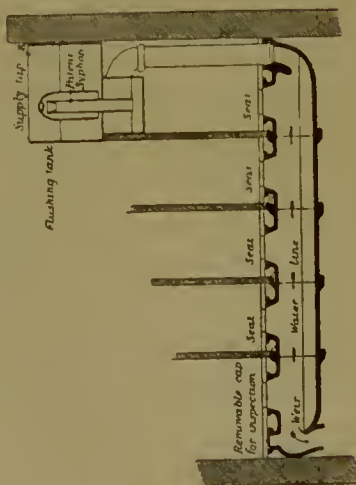


DESCRIPTION.—A, tumbling pattern flushing scoop, tipping to position B; C, grating; D, closet shoot; E, annular water-retainer; G, water seal trap. Slops from kitchen-sink collect in tumbling scoop A, which tips when full, so flushing out annular chamber D and trap G.



TROUGH CLOSET RANGE, WITH AUTO-
MATIC ANNULAR SYPHON FLUSH
TANK.

FIG. 30.



the waste water from a sink, in an apparatus known as an "automatic flush." These flushes are made in various forms—that shown in the diagram being known as the "tumbling bucket flush." The object of this appliance is to collect small intermittent discharges of water, until enough has been stored to constitute an efficient flush, when the apparatus automatically and quickly discharges itself. These automatic flushes are used for various purposes in sanitary work, such as the flushing of drains, urinals, and, what are called, trough closets, etc., and when properly constructed are found to be thoroughly efficient for those purposes.

Before leaving the subject of water-closets, what is called the "trough closet" may be shortly referred to. These furnish a cheap form for public latrines, and the illustration (Fig. 30) shows a good and simple type of this class. It consists, as will be seen, of a long trough, formed of sections of salt-glazed stoneware. At one end a weir is formed, which has the effect of always maintaining a certain depth of water throughout the length of the trough. At the other end is a large flush pipe directed towards the weir, the flush being obtained by means of an automatic flushing tank; the form shown in the illustration is that known as the annular syphon automatic flush. This trough is placed under a range of w.c. seats not shown in the illustration; its action is as follows:—The water-tap shown supplying the tank is regulated so as to fill the tank in a period of time the length of which varies, according to the frequency of usage of the closets. When the tank has thus been filled up, to the level of the inner pipe of the annular syphon, the water begins to flow in a small stream through the syphon pipes. This flow gradually creates a vacuum, and so draws the water more and more rapidly into the syphon pipes until they become completely filled; the syphon then comes into action, and the entire contents of the tank are discharged in a few seconds. This vigorous flush drives the entire

contents of the tank before it, over the weir at the opposite end, and so through the intercepting trap (which should always be fixed below such an apparatus) and into the soil-pipe or drain.

Other Fittings.—With regard to the other sanitary fittings commonly found in houses, such as baths, basins, sinks, &c., little further need be said, as the points already fully described in speaking of water closets, in regard to the necessity for all these appliances and their waste pipes being thoroughly self-cleansing, applies with equal force to this class of fittings. It is a popular but mistaken idea that the liquid wastes from these fittings, being comparatively clean as compared to those from water closets, do not require the same care as regards disconnection and ventilation, and that any waste-pipe air finding its way into the house will not cause danger or offence. This, however, is entirely a fallacy. These wastes include dirt and grease from our bodies mingled with soap used in washing, the wastes from cooking including such offensive liquids, from kitchen sinks, as water used for boiling cabbages, meat, &c. All these substances deposit more or less on the interior surfaces of the waste pipes, notwithstanding the most efficient flushing, and as all of them rapidly decay and become offensive, clearly the admission into the house of air which has passed over them must be carefully guarded against. The arrangements for effecting this object have already been shown, and the necessity for fixing intercepting traps as close as possible under each individual fitting has already been mentioned.

It is impossible in the space here available to describe in detail the numerous forms which fittings of this class take. It will be sufficient guide to the inspector to judge of such fittings by this simple test : *Are they thoroughly self-cleansing?*

SEWAGE DISPOSAL.—Sewage varies according to locality, season, weather, and hour of day; it is very complex in its nature, and its component parts are unstable in character. In order to

obtain the greatest amount of good from a sewerage system it is necessary that organic wastes shall be discharged at the sewer outlet in their fresh condition before putrefaction has set in, and they then must be reduced to a state of complete oxidation without the intervention of dangerous, offensive decomposition. In all places, where it is possible, the safest destination of sewage is the ocean, where, by the action of the waves, the offensive matter is broken up and thoroughly disintegrated. Provided due care is exhibited in arranging the sewer outfall, there should not be any likelihood that any of the discharged sewage could be driven back upon the neighbouring foreshores where it might become a pestilent nuisance. It is not possible, however, always to arrange that the ocean shall be the destination of sewage, and as improper sewage disposal, and insanitary conservation of refuse matters have a most pernicious influence upon health, it becomes necessary to so purify sewage that it may be discharged into any adjacent water course without any subsequent change. To render the effluent of sewage innocuous, the organic wastes of human life must be so treated that they will be finally and completely consumed without any offensive putrefaction; and, to obtain such a purified effluent, the best and most natural system is to apply sewage to the land. The effective treatment of sewage upon the land, depends for its action upon certain micro-organisms which exist in the upper layers of the soil, and by their oxidising powers change highly complex organic compounds into those mineral substances which are in themselves innocuous. It is necessary, therefore, to encourage the growth of the micro-organisms which possess this power of destroying the dangerous portions of sewage, for all satisfactory types of sewage treatment involve the distinegration and disposal of suspended solid matter, and the conversion of the soluble organic residua into harmless constituents of the effluent, these organic residua being resolved by oxidation

into stable and inert materials. As a general rule each species of micro-organism is poisoned or killed off by its own products, but the life products of one species form food for another species. Broad irrigation of sewage is devoid of all offence provided the land used is suitable for the purpose and of sufficient space so that a proper amount of rest may be given to each portion. Unfortunately sewage farms are not always large enough, and as there has always been a difficulty when crude sewage is applied to the land, through it becoming caked on the surface, there is a tendency for the land to become sewage sick through want of proper aeration. For to encourage the resolving powers of the micro-organisms and to maintain the requisite oxidising processes, renewed supplies of oxygen must frequently enter the soil. Therefore by absorption and aeration the capacity of the soil to purify sewage is increased, but if the soil is not properly aerated, decomposition will take on a pernicious form of putrefaction, which is maintained by organisms capable of living without air. Filtration does improve the purity of the effluent, and the purification of sewage by downward intermittent filtration, depends upon oxygen and time for its success. Denton has pointed out that "the capacity for soils to absorb water is no criterion whatever of their cleansing capability, whilst their retentive powers exercise great influence on the rate of percolation and the quality of the effluent." Very fine sand or any other loose soil used for filtration may remain saturated throughout its whole depth, and give space for air only near the surface, provided it has stood long enough for the liquid there to be evaporated. In filtration the suspended matters are arrested at the surface, and as the liquid descends it is brought into contact with an enormous surface presented by the air within the soil. "The mechanical separation of any part of the sewage by straining through sand, is but an incident, which, under some conditions, favorably modifies the result, but the

essential condition is the very slow motion of very thin films of liquid over the surface of particles, having spaces between them sufficient to allow air to be continually in contact with the films of liquid." Filtration with aeration has been tried, and probably if the mass of sewage could be held in a state of effervescence, due to injected air, for a sufficiently long time, its organic matter would be completely oxidised. Although sewage can be purified and partially oxidised by passing it through soil, still something more remains to be done before the resulting effluent can be considered pure enough to be turned without fear into a neighbouring watercourse.

To obviate the difficulties experienced through the caking of sewage on the surface of the soil the method of precipitation by chemical means was adopted. This form of treatment was followed by the formation of sludge, which is of a low manurial value, and is dangerous to health through its tendency to putrefy, and also by the destruction of those very organisms the growth and increase of which it is important to encourage. If lime alone is used for this purpose it forms a bulky precipitate with a low manurial property, and it fails to arrest decomposition. Neither complete purification nor any near approach to it can be effected by any practical chemical treatment; for there may be inefficient mixing, with a partial escape of the re-agent from combination, and although the resulting effluent is partially sterilized, yet when it reaches a larger body of water, dilution causes the antiseptic properties to vanish and secondary decomposition takes place. Chemical precipitation, therefore, fails to aid the processes of nature so as to prevent annoyance and harm, for it destroys the oxidising organisms and yields an effluent in which there is always a considerable amount of polluting matter left. Notwithstanding the partial failure of these methods the scientific world had reached the threshold of real knowledge concerning the processes by which organic matter is converted into those mineral compounds

which inoffensive and inert in themselves, become in the economy of life the direct food of growing plants. In all the previous methods of dealing with sewage the chief object has been to get rid of the offensive matters without any regard to their value as a manure. As the supply of phosphoric acid, and combined nitrogen is not unlimited, and as these are the scarcest items of plant food, it becomes a serious matter to countenance wholesale destruction of these essentials of life. As every grain of nitrate rescued from sewage is a clear gain to the community, any method which can effect this gain is worthy of consideration, more especially if it will enable us to restore to the earth, without danger to the community, those matters which have been discarded by man. It is becoming more and more clear every day that we are getting upon the right track to follow fairly and honestly the methods of Divine Nature, and that she is rewarding us with an insight into the possibilities of her system far exceeding the most sanguine anticipations of the past. In sewage there exist certain germs which are harmful and ought to be deracinated, and certain other germs which are useful to plant life : some of which appear to be the concomitants of disease, while others are the universal scavengers which convert dead organic matter into the condition necessary to fit them to become again food for various forms of organic life. We have already noticed Mills' statement that "the essential condition of sewage purification is the very slow motion of very thin films of liquid, over the surface of particles, having spaces between them sufficient to allow air to be continually in contact with the films of liquid." This condition combined with action of those micro-organisms which in the soil promote oxidation, has been found to be the rational method of treating sewage. The bacterial treatment of sewage by which the genesis and living of the micro-organisms, necessary to promote the oxidation of the complex constituents of sewage, is encouraged,

is now accepted as the true and rational method of sewage treatment. By this method sewage is so changed that it ceases to be offensive, and its effluent is charged with all the valuable manurial qualities. Different organisms are brought into action by the different methods, but it matters little whether anaërobic or aérobic microbes accomplish the success so long as a good result is obtained. In the septic tank, which after all is merely a modified cesspool, anaërobic organisms commence the work which is completed in the filter beds by aérobic organisms. It is difficult, however, to appreciate the value of the delay which occurs in the method of the septic tank when, as the Ducat filter method seems to have proved, the aérobic organisms in the filter beds can perform the whole of the work required. As far as one can see the septic tank as such is not at all necessary if "the whole of the purifying action is due to the encouragement of the genesis and living of the aérobic organisms." The whole theory then of what happens to sewage in a bacterial tank may be summed up as oxidation in the presence of micro-organisms which find their proper amount of pabulum in the sewage supplied. As regards the effluent it is not possible that all the germs are retained by the filter bed, for as these micro-organisms pass to and fro, some effect a lodgment in the bacterial bed, while others pass away with the effluent. The biological processes at work in the filter beds prove inimical to those germs thought to be connected with morbid processes in the human subject, and without doubt these processes are assisted by the many important changes which occur in the bacteriological composition of sewage during the passage of this liquid through the miles of sewers. Possibly the discharge of such effluents from bacterial beds is to be viewed with caution when they are allowed to mingle with a fresh water stream, but when they are discharged into sea water those micro-organisms which may pass out along with the effluent are almost certain to be destroyed.

Broad irrigation, intermittent downward, filtration, and chemical treatment have all been tried on a large scale and found more or less "wanting"! The septic tank and the Moncrieff cultivation filter methods have the objection of producing preliminary, and offensive putrefactive changes before the aerobic and inoffensive stage of the process is reached. The Ducat filter method, wherein the complete breaking down of the organic matters into inert chemical substances, takes place in one act, and without any perceptible putrefactive offence, would appear to be the coming method. In this, by means of super-imposed layers, a constantly and naturally aerated filtering material, which satisfies to the full, Mills' conditions of sewage purification, we have a method afforded which has proved itself capable of doing all in the way of inoffensive purification, while the sewage trickles through an aggregate thickness of about 8ft. of such layers—a process which occupies a space of only about three-quarters of an hour. Here then we have a process which is in effect that of Mother Nature in the soil, but one wherein the speed of the operation is immensely hastened over that possible in natural soil conditions, and where, consequently, a much smaller area of purifying material is required than is the case in any known broad irrigation or intermittent downward filtration applied to even best natural soil. Thus, while at the Botany Sewage Farm, near Sydney, which has an open, almost pure sand soil, with excellent under-drainage—it has been found that even such soil is over-taxed when treating less than 60,000 gallons per acre per day, by the Ducat method, with a depth of 8ft., it has been proved possible to deal with 250 gallons per yard of surface per day, which is at the rate of 1,000,000 gallons per acre. In this method it may, therefore, be said without presumption, that modern research and trial in this direction have enabled us actually to improve on Nature. It has thus placed in our hands a method which it is not perhaps altogether Utopian to hope, may, in

the not distant future, render available to us a means which, while preserving all the cleanliness and convenience of the water carriage system, will enable the sewage from each individual house to be dealt with where it is produced, and without offence—Dealt with in a manner which, without any attention or expense whatever, except that of first cost, will thus simply supply so important a link in the necessary cycle of ever constant natural change by restoring the water supply fouled by the natural operations of the animal body, and by the usage of close habitation, to its pristine purity. Such a time is not yet, but it would seem to be approaching, and the far-reaching influence for good which would ensue could our complicated and costly sewers and outfalls be done away with, and the natural water channels restored to their early purity, so found sufficient for all our purposes, is a consummation well worthy to be looked forward to and prayed for.

SAVING OF LIFE THROUGH SANITARY WORKS.

The increase of a population is an indication of increasing prosperity of a country, and the influence exerted by sanitary science on vital statistics is observed in the death rate. It is a well-known fact that the decrease in the mortality of any city has been very great after the establishment of a proper water supply, but the after installation of a proper system of sewerage has brought about a still greater decrease, and the experience of all cities which have engaged in such works of a high state of civilisation has been, that, as these systems have been extended, so the state of public health has been raised to a higher standard. In considering such results, due consideration must be given to climate, for a hot climate is likely to bring about putrefaction more quickly than a cold one. Many years ago the city of London was much affected with ague, but since the

sewerage system has been perfected and extended, this disease has almost totally disappeared. During eight years after the extension of the improvements of the sewerage system, in London, the saving of life amounted to 15·76 per cent; in Brighton, 16·57 per cent.; in Portsmouth, 20·62 per cent.; Bristol, 12·5 per cent.; Cardiff, 29·1 per cent.; Birmingham, 14·02 per cent.; Nottingham, 34·19 per cent.; Liverpool, 11·51 per cent.; Manchester, 23·1 per cent.; Oldham, 24·49 per cent.; Bradford, 18·40 per cent.; Leeds, 23·14 per cent.; Newcastle-on-tyne, 26·84 per cent. During the period extending from the year 1888 to the year 1898, the death rate in the metropolis of Sydney, New South Wales, decreased from 189·2 per 10,000 of the population to 151·8. This great decrease in the mortality of the metropolis of Sydney has occurred since the installation of, and during the extension of the sewerage system, and although other sanitary reforms have been effected during this period of time, still there is no doubt that the sewerage system is the prime factor in furthering this decrease, in that it has assisted the other reforms so that they have been enabled to be of great benefit. In the year 1888 the death-rate at one year of age was 66·07 per 10,000 of the population, in the year 1897 it fell to 38·0, and rose again slightly in the year 1898 to 46·1. In the year 1888 the death-rate at 5 years of age was 121·9 per 10,000 of the population, while in 1897 it was 48·2 and in 1898, 64·2. Surely such a decrease must be considered a triumph for our sanitary systems. Evidence is abundantly forthcoming of the benefits of sanitation, in the improved death-rate and the material diminution of disease. The usual criteria adopted as evidence of the health of any community are—the general death-rate—the zymotic death-rate—and the infant mortality. The gross death-rate is a fairly simple, and in the main an accurate measure of the prevalence of disease. The zymotic death-rate is not so safe a standard. The gross death-rate in the city of Sydney has during the last 8 years

materially decreased ; the zymotic death-rate has also decreased during the progress of sanitary measures, although at times it has assumed alarming proportions. It is to be specially noticed that the diminution of mortality has been especially marked in those districts which have been provided with a proper system of sewerage. Although so much has been achieved more remains to be done, for the effect of insanitary conditions is seen in the miserable physique of the masses, their dirt and immorality, and the appalling sacrifice of infant life. "Now the aim of house sanitation is to lower the death-rate and to promote the health and well being of the house occupants. Everyone has a direct interest in lowering his own death-rate and that of those dependent on him, and in living his life under such conditions as are most conducive to health, happiness and capacity for work." It is therefore to be remembered that when a proper sewerage system is provided it is incumbent upon the owner to set his house in order and to connect it properly with the main sewer. In estimating the value of a sewerage system it is not only necessary to take into consideration the decrease in mortality and the saving of life, but also to take account of the sickness rate. If this rate is calculated according to the latest methods and reduced to a money value it will be found approximately that in the City of Sydney about £20,000 have been saved during the last eight years, and consequently it is fair to assume that if all the houses were fitted with perfect sanitary systems a much greater saving would result. Alas, owing to human indifference and ill-judged economy, full acceptance of the benefit of the sewerage system has not been taken, and property owners can only gradually be made to appreciate the value of sanitary works in raising the standard of health and in preventing sickness. It is very necessary to distinguish between a house drain and a sewer, and it must be remembered that although a sewerage system may be perfect, a connecting house drain may through indi-

vidual neglect become very foul and a source of disease. No sanitary system is automatic, and consequently house drains need attention so that they may always be clean. In order to prevent the ingress of foul air from drains, etc., into houses, water traps have been invented, but these traps need constant attention or they may become a source of disease rather than a safety. Neglect of a house drain is a sanitary fault and will surely beget disease.

SANITARY LAW.

"It has been proved, over and over again, that nothing is so costly in all ways as disease, and that nothing is so remunerative as the outlay that augments health; the record of deaths only registers, as it were, the wrecks which strew the shore, but it gives no account of the vessels which were tossed in the billows of sickness, stranded and maimed as they often are by the effects of recurrent storms." To combat all this, and to place affairs on a better footing, sanitary law has been promulgated, so that with a better state of national health there will be a larger amount of national wealth. One of the first duties of any authority, and which is required by English Public Health Act (sections 189-191), is the appointment of an inspector of nuisances, and by the London Act, 1891, the New South Wales Act, 1898, the Victorian Act, 1890, the Queensland Act, 1884, the South Australian Act, 1888, and the Tasmanian, 1885, all persons applying for such appointments shall be holders of a certificate of such body as the supreme health power may from time to time determine. This health power is in England the Local Government Board, and in the various Colonies the various Central Boards of Health. Each of these authorities, by order, define the various duties of the inspector.

The Board shall appoint an Inspector or Inspectors, as may be deemed necessary by the Central Board, who shall act under the supervision and direction of such Board or its Secretary, or under the direction of the Officer of Health, or, in cases where no such directions are required, shall perform all the duties specially imposed upon an inspector by the Health Act, or by any other statute or regulations, so far as the same apply to his office. He shall be paid a salary, and shall hold office subject to the pleasure of the Central Board.

1. He shall attend all meetings of the Board when so required.
2. He shall, by inspection of the district, both systematically and at certain periods, and at intervals as occasion may require, keep himself informed in respect to the insanitary conditions existing therein that require abatement, and shall send in a report to each regular meeting of the Board.
3. On receiving notice of the existence of any insanitary condition within the district, or of any breach of any regulations made by the Board or the Central Board for the suppression of insanitary conditions, he shall, as early as practicable, visit the spot, and enquire into such alleged insanitary conditions or breach of the regulations.
4. He shall report to the Board the existence of any noxious or offensive businesses, trade or manufactories within the district, and the breach or non-observance of any regulations made in respect of the same.
5. He shall report to the Board any damage done to any works of water supply, and also any case of wilful or negligent waste of water supplies, or any fouling by gas, filth or otherwise of water used for domestic purposes.
6. He shall from time to time, and forthwith on complaint or information, visit and inspect the shops and places, and vehicles and stands, kept or used for the preparation or sale of butchers' meat, poultry,

fish, fruit, vegetables, corn, bread, flour, milk, or any other article to which the provisions of the Public Health Act, in this behalf shall apply, and examine any animal, carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, milk, butter, eggs, cheese, or other article, solid or liquid, as aforesaid, which may be therein ; and in case any such article appear to him to be intended for the food of man, and to be unfit for such food, or to be diseased, or unsound, or unwholesome, he shall take such proceedings as may be necessary in order to have the same dealt with by justices : Provided that in any case of doubt arising under this clause, he shall report the matter to the Officer of Health with a view of obtaining his advice thereon.

7. On receiving written notice from any person having in his possession any article which is diseased, or unsound, or unwholesome, or unfit for the food of man, he shall, provided that the notice specifies such article and contains sufficient identification of it, remove or cause such article to be removed as if it were refuse or scavenger's waste.

8. He shall, when and as directed by the Board or Central Board, procure and submit samples of food, drink, or drugs, or substances used in the preparation of food, drink, or drugs, suspected to be adulterated, to be analysed by the analyst appointed under the Sale of Food and Drugs Act, and the Food and Drugs Act Amendment Act, or any registered or qualified analyst, and upon receiving a certificate stating that the articles of food, drink, or drugs are adulterated, cause a complaint to be made, and take other proceedings prescribed by that Act.

9. He shall give immediate notice to the Officer of Health of the occurrence within the district of any contagious, infectious, or epidemic disease ; and whenever it appears to him that the intervention of such officer is necessary, in consequence of the existence of any insanitary condition, or of any overcrowding

in a house, he shall forthwith inform the Officer of Health thereof.

10. He shall enter from day to day, in a book provided by the Board, particulars of his inspections, and of the action taken by him in the execution of his duties. He shall also keep a book, to be provided by the Board, so arranged as to form, as far as possible, a continuous record of the sanitary conditions of each of the premises in respect of which any action has been taken under the Health Act, or under any other statute or regulation, and shall keep any other systematic records that the Board may require.

11. He shall, at all reasonable times, when applied to by the Officer of Health, produce to him his books, or any of them, and render to him such information as he may be able to furnish with respect to any matter to which the duties of inspector relate.

12. He shall make all such inspections as are required under the Health Act, and when required by the Officer of Health, he shall make such inspection as that officer may direct, and shall report to him without delay the result of such inspection.

13. He shall if directed by the Board to do so, superintend and see to the due execution of all works which may be undertaken under its direction for the suppression or removal of insanitary conditions within the district.

14. In matters not specially provided for in these regulations, he shall observe and execute all the lawful orders and directions of the Board.

The most important part of an inspector's work is the dealing with nuisances, and it is highly necessary for him to be able to determine how to deal with them, and to be well acquainted with the necessary mode of procedure. Nuisances may be divided into two classes, viz. :—

1. General nuisances.
2. Trade nuisances.

Under the 91st section of the Public Health Act, London, 1875, for the purposes of the Act, nuisance is defined—

1. Any premises in such a state as to be a nuisance or injurious to health.

2. Any pool, ditch, gutter, watercourse, privy, urinal, cesspool, drain or ash-pit, so foul, or in such a state as to be either a nuisance or injurious to health.

3. Any animal so kept as to be either a nuisance or injurious to health.

4. Any accumulation or deposit which is a nuisance or injurious to health.

5. Any house, or part of a house, so overcrowded as to be dangerous or injurious to the health of the inmates, whether or not members of the same family.

6. Any factory, workshop, or work place not kept in a cleanly state, or not ventilated in such a manner as to render harmless, as far as practicable, any gases, vapours, dust, or other impurities generated in the course of the work carried on therein that are a nuisance, injurious to health, or so overcrowded while work is carried on therein as to be dangerous or injurious to the health of those employed therein.

7. Any fireplace or furnace which does not, as far as practicable, consume the smoke arising from the combustible used therein, and which is used for working engines by steam; or in any mill, factory, dyehouse, brewery, bakehouse, or gaswork, or in any manufacturing or trade process whatsoever; and, "Any chimney (not being the chimney of a private dwelling-house) sending forth black smoke in such quantity as to be a nuisance, shall be deemed a nuisance liable to be dealt with summarily."

"Where any quarry dangerous to the public is in open or unenclosed land within fifty yards of a highway or place of public resort dedicated to the public, and is not separated therefrom by a secure and sufficient shed, it shall be deemed a nuisance." "A tent, van, shop, or similar structure used for human habitation, which is in such a state as to be a

nuisance or injurious to health, or which is so overcrowded as to be injurious to the health of the inmates, whether or not members of the same family, is also deemed a nuisance.

DEFINITIONS.

Building—Any wooden structure on wheels, those without foundations, boats, vessels, ships, tents, vans, sheds, and other similar structures used for human habitation.

House means and includes dwellings of any kind, schools, hotels, licensed victuallers' premises, factories, workrooms, common or other lodging-houses, or other buildings or premises.

Dwelling-house means any inhabited building, and includes any yard, garden, outhouse, and appurtenances belonging thereto, or usually enjoyed therewith, and includes the site of the dwelling-house so defined. "House," "dwelling-house," or "building" respectively includes the curtilage of a house, dwelling-house, or building.

Curtilage—A courtyard, back-side, or piece of ground lying near a dwelling-house.

Owner means the person for the time being entitled to receive the rent of the land or premises in connection with which the word is used whether on his own account or as the agent of or as trustee for any other person, or who would be entitled to receive the same if the lands or premises were let at a rent.

Occupier includes a person having the charge, management, or control of a building or of the part of the building in which the patient is, or to which the enactment relates, and, in the case of a house, the whole of which is let out in separate tenements, or in the case of a lodging-house, the whole of which is let out to lodgers, the person receiving the rent payable by the tenants or lodgers, either on his own account

or as the agent of another person, and in the case of a vessel means the master or other person in charge thereof.

Slaughter-house includes the buildings and places commonly called slaughter-houses, and any other building or place used for slaughtering cattle, sheep, pigs, or other animals of any description.

Sanitary convenience includes water-closets, urinals, earth-closets, privies, and any similar convenience.

Boxes—The receptacles used in earth closets.

Cesspit—Any cesspit, tank, box, or other receptacle for faecal matter or urine not discharged by water.

Closet—Any privy, water-closet, earth-closet, or place used for the reception of faecal matter or urine or earth mixed therewith.

Earth-closet shall mean a seat similar to the seat of a privy, and having underneath a bucket or other receptacle for excrement, with convenient apparatus for the supply of as much dry powdered earth or other deodorising material as will completely cover the excrement every time the closet is used by any person.

Water-closet shall mean a pan of a pattern approved by the Local Board, with a seat similar to that of a privy, having a trapped and ventilated soil-pipe, and a water supply from a cistern disconnected from any pipe containing water for household use.

Sewer shall mean and include sewers and drains of every description, except drains to which the word drain interpreted as aforesaid applies.

Drain means any drain used for the drainage of one building only, or of premises within the same curtilage, and made merely for the purpose of communicating therefrom with a cesspool or other like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed.

Street shall mean and include any highway and any public bridge, and any road, lane, footway, square, court, alley, or passage, whether a thoroughfare or not.

Premises and Land means and includes messuages, buildings, lands, and hereditaments of every tenure, also rivers, streams, wells, and waters of every description, also easements.

Those sections of the various Public Health Acts which relate to nuisances, and the putting into force of vested powers so as to secure the proper sanitary condition of all premises, are very material for the study of the Sanitary Inspector, and will be dealt with further in the Supplement to this work, viz., on Sanitary Law.



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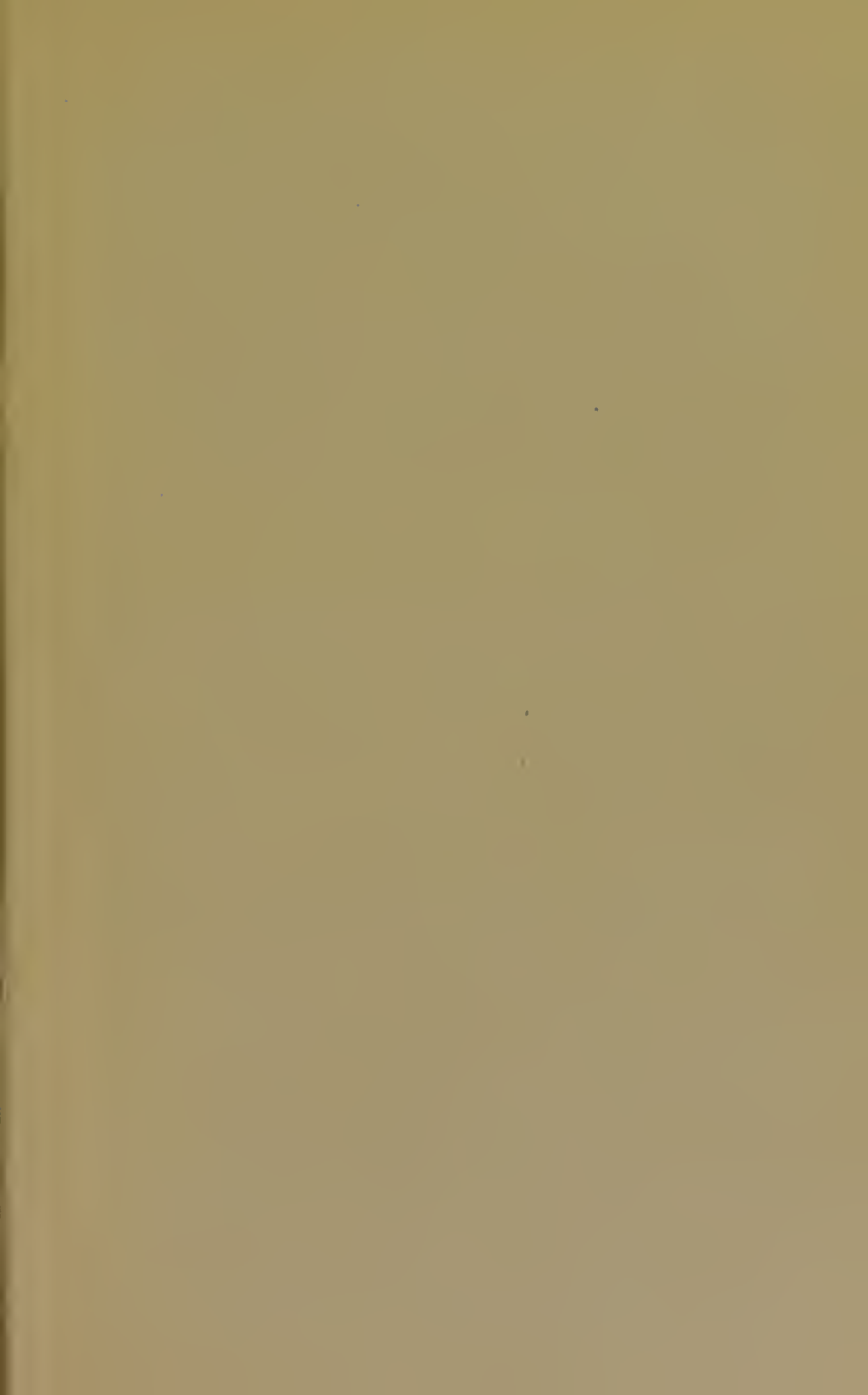
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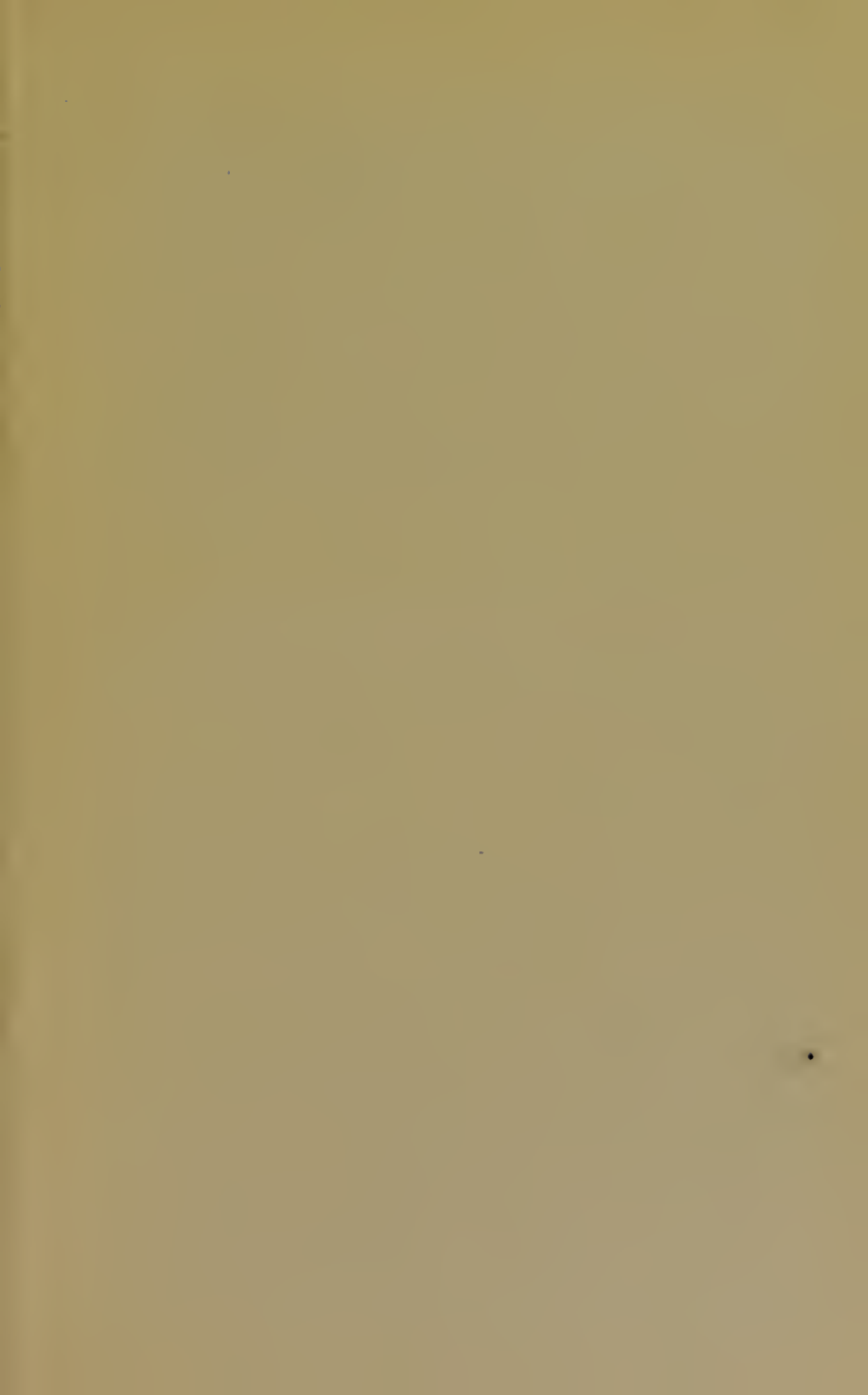
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